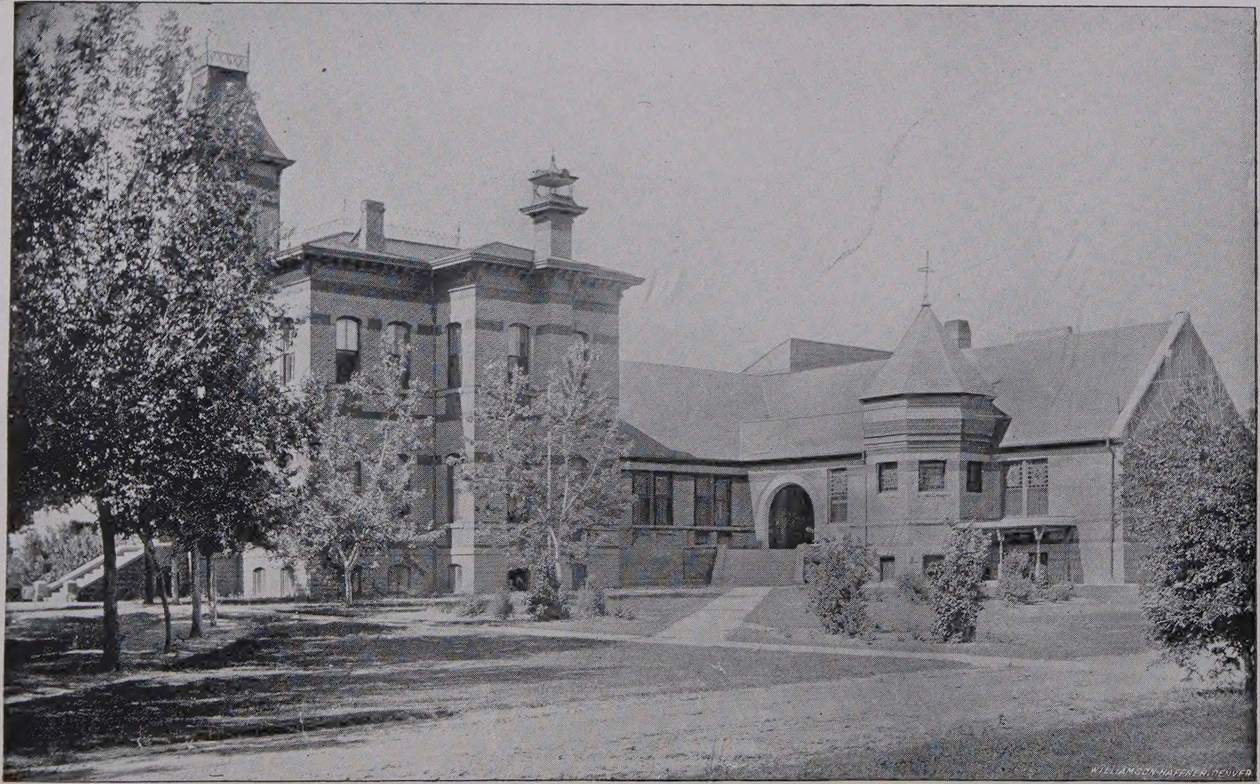


MAIN BUILDING.

EIGHTEENTH ANNUAL REPORT

OF

THE STATE BOARD OF AGRICULTURE

AND

THE STATE AGRICULTURAL COLLEGE

INCLUDING

THE NINTH ANNUAL REPORT

OF

THE AGRICULTURAL EXPERIMENT STATION

FORT COLLINS, COLORADO

1896

DENVER, COLORADO:
THE SMITH-BROOKS PRINTING CO., STATE PRINTERS
1897

STANDING COMMITTEES

EXECUTIVE

A. L. Kellogg — J. J. Ryan — J. E. DuBois — A. S. Benson — Alston Ellis

FINANCE

A. S. Benson — J. E. DuBois — E. H. Snyder

FARM AND STOCK

B. F. Rockafellow — J. E. DuBois — J. L. Chatfield

FACULTY AND COURSES OF STUDY

A. L. Kellogg — Alston Ellis — Eliza F. Routt

BOTANY, HORTICULTURE, AND ENTOMOLOGY

J. L. Chatfield — Eliza F. Routt — B. F. Rockafellow

MATHEMATICS, ENGINEERING, AND MILITARY SCIENCE

E. H. Snyder — A. L. Kellogg — J. E. DuBois

MECHANICS AND CHEMISTRY

J. E. DuBois — E. H. Snyder — J. L. Chatfeld

COLLEGE BUILDINGS AND PERMANENT IMPROVEMENTS

J. E. DuBois — Alston Ellis — A. S. Benson

DOMESTIC ECONOMY AND LIBRARY

Eliza F. Routt — A. L. Kellogg — B. F. Rockafellow

Board of Instruction.

ALSTON ELLIS, A. M., Ph. D., LL. D.,
President, and Professor of Political Economy and Logic.

JAMES W. LAWRENCE, B. S.,
Professor of Mechanical Engineering and Drawing.

MAUD BELL,
Professor of History, Literature, and German.

LOUIS G. CARPENTER, M. S.,
Professor of Civil and Irrigation Engineering.

CHARLES S. CRANDALL, M. S.,
Professor of Botany and Horticulture.

CLARENCE P. GILLETTE, M. S.,
Professor of Zoology and Entomology.

GRACE ESPY PATTON, B. S.,
Professor of English and Sociology.

WILLIAM J. MEYERS, B. S.,
Professor of Mathematics.

DANIEL W. WORKING, B. S.,
Secretary of the Faculty.

WELLS W. COOKE, B. S., A. M.,
Professor of Agriculture.

WILLIAM P. HEADDEN, A. M., Ph. D.,
Professor of Chemistry and Geology.

HARRY D. HUMPHREY, 1st LIEUT. 20th INF., U. S. ARMY,
Professor of Military Science and Tactics.

THEODOSIA G. AMMONS,
Professor of Domestic Economy.

JACOB A. CHRISTMAN,
Principal of the Commercial Department.

INSTRUCTORS AND ASSISTANTS.

L. D. CRAIN, B. M. E., *Mechanical Engineering and Drawing.*

J. D. STANNARD, B. S., *Physics and Civil Engineering.*

FRANK L. WATROUS, *Agriculture.*

JACOB H. COWEN, B. S., *Botany and Horticulture.*

CHARLES J. RYAN, *Chemistry.*

ROBERT E. TRIMBLE, B. S., *Meteorology and Irrigation Engineering.*

LATHROP M. TAYLOR, B. S., *Stenography and Typewriting.*

CORYDON A. WOODY, B. S., *Principal Preparatory Department.*

EDWARD M. TRABER, *Latin and Greek.*

EDWARD B. HOUSE, B. S., E. E., *Mathematics.*

EMMA A. GILLETTE, *Zoology and Entomology.*

ALLEN P. GREENACRE, B. S., *Forge-Room Work.*

WILLIAM GARBE, *Foundry Practice.*

CHARLES F. MERGELMAN, *Floriculture and Landscape Gardening.*

LIBRARIAN.

MARGUERITE E. STRATTON, B. S.

Letter of Transmittal.

TO HIS EXCELLENCY,

A. W. McINTIRE,

GOVERNOR:

As required by law, I herewith transmit for your consideration my annual report as Secretary of The State Board of Agriculture, together with it being the report of the President of the State Agricultural College.

Respectfully submitted,

D. W. WORKING.

The State Agricultural College,
Fort Collins, Colorado,
December 14, 1896.

REPORT OF THE SECRETARY.

The financial statement hereto appended shows in detail the receipts and expenditures of the State Agricultural College for the fiscal year ended November 30, 1896. It is believed that the statement needs no explanation. It may, however, be worth remarking that the receipts credited to the Land Income Fund, the Special Fund, and the Annie Jones Library Fund are not receipts from the State; also that the State contributed to College support and improvement during the year only the amounts credited to the Tax Fund and the Improvement Fund, that is, $43,151.21, and that this last sum should be further reduced by the amount of Tax Fund certificates outstanding at the end of the fiscal year.

During the year the College has prospered. While it is true that an increased attendance is the principal outward sign of this prosperity, it is also true that those most deeply interested in the results of the work of the College, as well as most faithful and effective in their efforts to make that work what it should be, earnestly desire that thoroughness and soundness of scholarship, which are more to be sought after than numbers, may always be the principal thing the College shall delight to promote and the State be proud to commend and substantially encourage. The elaborate report of the President of the College makes it unnecessary here to dwell upon matters discussed in that report, to which the reader is referred for full information.

In previous reports I have made and reiterated suggestions for legislation concerning the Board of Agricul-

ture and its officers. These suggestions availed nothing. No recommendations will be made at this time. If opportuity is offered, I shall gladly appear before any interested legislative committee to furnish information concerning the work and needs of the Board and College or to make suggestions for legislation in their interest.

The financial statement which follows was approved by the Finance Committee of The State Board of Agriculture, and on recommendation of the Committee was adopted by the Board.

D. W. WORKING.

APPENDIX I.

SECRETARY'S STATEMENT OF RECEIPTS FROM ALL SOURCES AND DISBURSEMENTS FOR ALL PURPOSES DURING THE FISCAL YEAR BEGUN DECEMBER 1, 1895, AND ENDED NOVEMBER 30, 1896.

STATE FUNDS.

Receipts:			
Tax Fund	$ 31,163.80		
Tax Fund certificates outstanding	1,988.41	$ 33,152.21	
Land Income Fund		5,416.63	
Special Fund		1,957.85	
Annie Jones Library Fund		2,692.90	
Improvement Fund		9,999.00	$ 53,218.59
Disbursements:			
Certificates outstanding Dec. 1, 1895.		$ 551.54	
Salaries		13,269.83	
College Departments—			
President's office	$ 403.10		
Secretary's office	108.95		
Mechanical Engineering	3,302.17		
Civil and Irrigation Engineering	422.87		
Farm	1,917.49		
Botany and Horticulture	1,238.22		
Zoology and Entomology	375.61		
English and Sociology	94.15		
Chemical	81.16		
Mathematical	112.16		
Domestic Economy	530.40		
Commercial	548.29		
History and Literature	5.00		
Military	75.76	$ 9,215.33	

Disbursements—Continued.

Library			931.83
Student Labor			679.04
Furniture			723.71
Current Expenses—			
Coal	1,615.20		
Electric light	449.00		
College Catalogue	395.00		
Hotel and traveling expenses	467.11		
Supplies and fixtures	535.55		
Water rent	300.00		
Commencement expenses	109.50		
Freight and express	71.12		
Telephone rent	36.00		
Inspecting boilers	10.00		
Assessments on ditch stock	145.17		
Postoffice box rent	8.50		
Membership fee A. A. A. C. and E. Stations	10.00		
Carrying College mail	82.00		
Telephone and telegraph tolls	13.85		
Printing circulars	30.60		
Tuning piano	11.00		
Attorney fee	109.00		
Bust of Senator Morrill	45.00		
Printing annual report	98.80		
Cataloging Library	50.00		
Carpet for Chapel stage	51.80		
Stone walk	30.50		
Wire matting	32.00		
Class record books	10.46		
Matting for chapel aisles	50.96		
Repairs to telephone line	18.15		
Extra janitor service	2.50		
Extra instruction in Commercial Department	14.40	$	4,803.17
Fair exhibits			86.75
Insurance			832.50
The State Board of Agriculture			2,668.55
Farmers' Institutes			132.70

Disbursements—Continued.

Annie Jones Library			2,692.90	
General repairs			1,298.37	
Permanent Improvements			503.88	
Text-books and supplies			2,284.45	
Advertising			301.20	
Greenhouse			2,904.48	
Mechanical Building Heating Plant			418.54	
Flagging basement Main Building			100.00	
Flagging Forge-room			140.92	
Chemical Laboratory			3,042.39	
Plumbing Domestic Economy Building			225.26	
Advertising pamphlet			233.45	
Mechanical Building additions			4,727.80	
Remodeling Barn roof			450.00	$ 53,218.59

UNITED STATES OR "MORRILL" FUND.

Receipts:		
State Treasurer		$ 21,099.84
Disbursements:		
Salaries		$ 21,099.84

EXPERIMENT STATION FUND.

Receipts:			
In Local Treasury December 1, 1895		$ 3.73	
Local Treasurer—Canceled warrant		2.00	
United States treasury		15,000.00	
State Treasurer		2,379.24	$ 17,384.97
Disbursements:			
Salaries		$ 9,867.70	
Station Sections—			
Agricultural	$ 296.60		
Horticultural	132.41		
Entomological	139.34		
Chemical	181.39		
Meteorology and Irrigation	573.07	1,322.81	
Substations—			
Arkansas Valley	1,954.34		
Rainbelt	362.03		
San Luis Valley	80.88		
Divide	65.64	2,462.89	

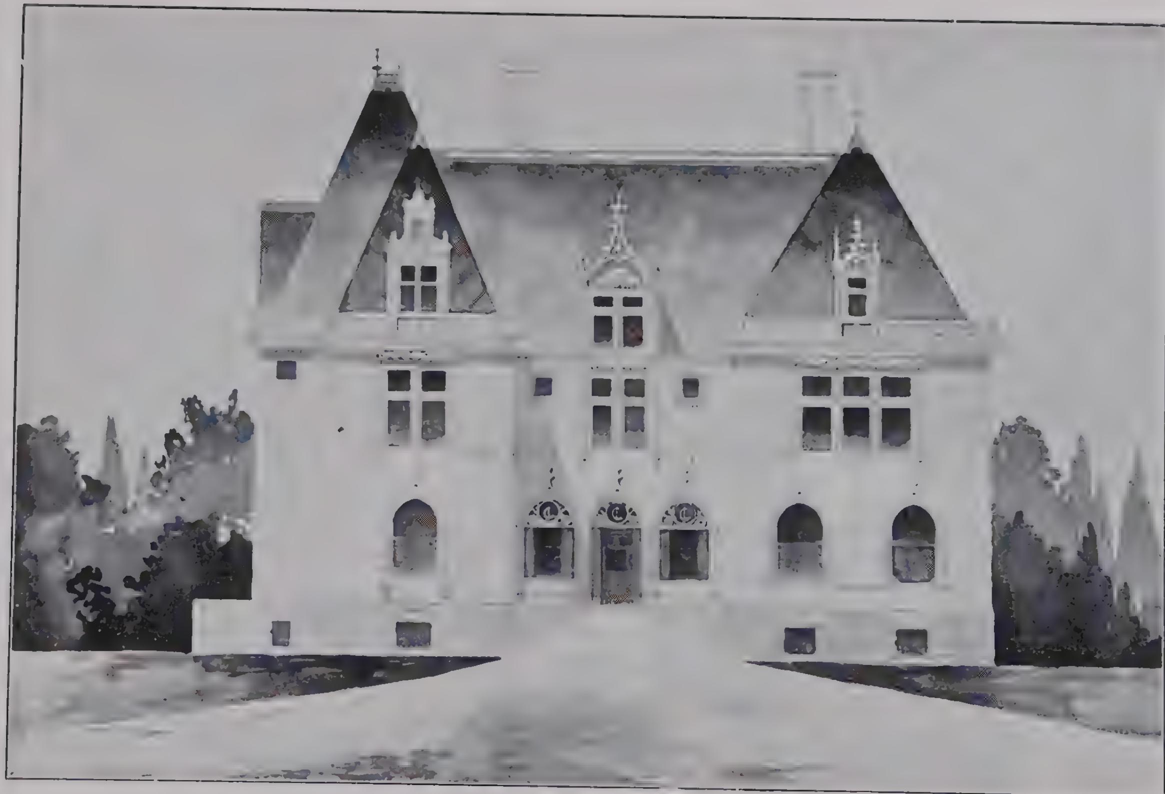
Disbursements—Continued.

Printing Bulletins..........................	485.95	
Stationery	54.50	
Feeding Experiment......................	1,195.00	
Contingent expense......................	10.00	
Traveling expense.........................	11.45	
Printing Annual Report................	100.00	$ 15,510.30
In Local Treasury November 30, 1896		1,874.67
		$ 17,384.97

APPENDIX II.

SECRETARY'S STATEMENT OF CASH RECEIPTS AND REMITTANCES FOR THE FISCAL YEAR BEGUN DECEMBER 1, 1895, AND ENDED NOVEMBER 30, 1896.

Receipts:			
Farm Department Fund		$ 1,026.82	
Horticultural Department Fund		197.12	
Coal Fund		45.18	
Mechanical Engineering Department Fund		29.65	
Text-book Fund		736.05	
Current Expense Fund		2.00	
Annie Jones Library Fund		180.00	
Zoology and Entomology Department Fund		40.74	
Civil and Irrigation Engineering Department Fund		1.65	
Domestic Economy Department Fund		2.10	
Insurance Fund		4.00	
Experiment Station Funds—			
Arkansas Valley	$ 580.92		
San Luis Valley	96.50		
Divide	36.85		
Rainbelt	5.20		
Feeding Experiment	1,575.78	$ 2,295.25	$ 4,560.56
Remittances to State Treasurer:			
Special Fund		$ 2,085.31	
Annie Jones Library Fund		180.00	
Experiment Station Fund		2,295.25	$ 4,560.56



CHEMICAL BUILDING.

PRESIDENT'S REPORT.

To The State Board of Agriculture:

Gentlemen—If what is presented under this heading finds its way into print, it will appear as a part of the "Eighteenth Annual Report of The State Board of Agriculture." The "if" is used advisedly; for of late years the printing of our reports by the constituted state authority has been somewhat spasmodic. The legislative act of April 19, 1895, makes provision for the publication of the class of reports to which ours belongs. The statute provides for an edition of two hundred and fifty copies of each report and limits its length to one hundred pages. Further, "it shall be the duty of the Secretary of State to place said reports, without delay, in the hands of the person authorized to do the public printing for publication." Our Seventeenth Annual Report was prepared in due season and filed in the authorized manner. No efforts made by me could secure its publication by the State. Finally, the report was taken to "the person authorized to do the public printing." It appeared in pamphlet form and covered sixty-four printed pages. The edition of fifteen hundred copies cost $98.80, which sum was paid out of the college fund.

SOME FRAGMENTS OF COLLEGE HISTORY.

The life of the College covers but a brief span of time. The State under whose statutes it is managed is just twenty years old. The act of Congress providing for its first endowment dates back to July 2, 1862, in territorial days. The "more complete endowment and

support" of the College came by act of Congress dated August 30, 1890. These congressional acts are best known as the first and second "Morrill Bills." They stand as a lasting monument to the perseverance and wisdom of their author.

The "Hatch Act," which became a law March 2, 1887, makes annual appropriation, by the Government, of $15,-000 for the support of an experiment station in connection with the College. These acts of the National Congress have furnished a regular revenue for college support which now amounts to about $43,000 annually.

An act of the Territorial Legislature, in 1870, made provision for the establishment of an agricultural college, to be named "The Agricultural College of Colorado," and gave it a location "at or near Fort Collins in the county of Larimer." The same act named a Board of Trustees, twelve in number. Some change in the personnel of this board was made by legislative act in 1872. Two years of "innocuous desuetude" passed. On February 13, 1874, the Territorial Legislature made an appropriation of $1,000 to aid the trustees, before named, in erecting buildings on the grounds then belonging to the institution at Fort Collins, provided said trustees should raise "by subscription, donation, or otherwise" the sum of $1,000 and expend the same on buildings and grounds. The act making this qualified appropriation did not go into effect until January 1, 1875.

The sum required to be subscribed or donated by private parties before the territorial appropriation could be made available for use, was readily obtained from public-spirited citizens of Fort Collins and vicinity. The Larimer County Land Improvement Company made a donation of ditch stock to the value of $600. Collins Grange made a subscription of $100. The remainder of the requisite sum was subscribed by private parties, a full list of whose names cannot be obtained at this writing.

The Collins Grange may justly be credited with action that saved the forfeiture of college rights. Inaction had continued until rights previously secured were in

jeopardy. The members of the grange appointed a picnic day and assembled in force on the college grounds. During the day twenty acres of college ground were sown to wheat and cottonwood cuttings planted along the north line of the grounds. This wheat land, in harvest time, produced a yield of 375 bushels.

The act of 1874 refers to "grounds now belonging to said institution." Before the close of the year 1872, lands amounting to 240 acres had been donated, to the trustees, already named by statute, for the use of the College, by the following-named persons: Arthur H. Patterson, 80 acres; Robert Dalzell, 30 acres; Joseph Mason, H. C. Peterson, and J. C. Mathews, jointly, 50 acres; and the Larimer County Improvement Company, 80 acres.

When the state constitution was adopted, the College, under a provision thereof, became an institution of the State of Colorado. Its location at Fort Collins was confirmed and its management passed into the control of the State, "under such laws and regulations as the General Assembly shall provide."

The first Board of Agriculture, under state appointment, met in the office of Governor John L. Routt, Denver, on March 19, 1877. The term of office of the members was determined by lot. The membership of the Board was as follows:—

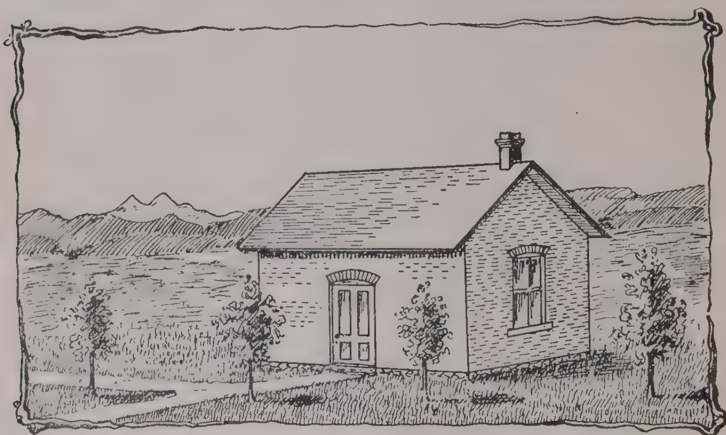
W. A. Bean, M. N. Everett.	Two years.
Harris Stratton, John J. Ryan.	Four years.
B. S. La Grange, W. F. Watrous.	Six years.
P. M. Hinman, John Armor.	Eight years.

W. F. Watrous was made President, and Harris Stratton Secretary of the Board.

The minutes of the Board meetings from the date of the initial meeting, just mentioned, to the present time are complete and legible. They are carefully recorded

and can be found in the office of the Secretary of the Board at the College.

The special appropriation and the private donation, before named—a total of $2,000—were used in making certain improvements on the grounds and in putting up a small brick building which later on did service as a chemical laboratory. This building, the oldest on the grounds, was one story high and contained a floor space about equal to that of an averaged-sized school-room.



FIRST COLLEGE BUILDING.

Since Colorado became a state, the proceedings of The State Board of Agriculture and the workings of The State Agricultural College, under its control, are matters of continuous record and frequent reports.

It is to be regretted that all the annual reports of the Board are not in print. It was false economy that saved a few dollars at the exepense of a broken series of reports. Doubtless there were times in the history of the College when a twelvemonth brought no startling or important changes in the management and growth of the institution; but what was done therein makes an integral part of college history and, as such, has a value that will increase as the years go by. What was done by the governing body and the faculty when the institu-

tion was getting upon its feet has more than a passing interest to those now doing or supervising college work.

I can find no written or printed copy of the First Annual Report, that for 1877. The minutes of the Board for that year set forth clearly and at length the proceedings of the three meetings held on March 19, September 11, and December 26. The financial statement presented at the final meeting of that year is certified to by President Watrous. The total receipts were $509.89. The expenditures footed up a total of $105.50. The close of the year found a healthy balance in the treasury.

The Second Annual Report—for 1878—is replete with interesting information. It covers forty-eight printed pages. In it is found an account of the Board's efforts to secure the erection of a proper building in which to begin college work. Messrs. W. F. Watrous, W. A. Bean, Harris Stratton, B. S. La Grange, and John J. Ryan constituted the Building Committee whose business it was, at the outset, to secure plans and specifications of the proposed building. The committee secured the services of an architect, George E. King, of Boulder, who thereafter designed a building the estimated cost of which was $7,000. Later the contract for putting up the building was awarded to H. C. Baker, of Boulder, at his bid of $7,000.

In June, 1878, the ground was broken, and on July 29th, everything was in readiness for laying the cornerstone. The report from which the following information is gleaned contains a readable description of the impressive Masonic ceremonies connected with putting the stone in place. The College is spoken of as "another link in the wonderful system of schools for the education of the people inaugurated with such success by the citizens of Colorado." Appropriate addresses were made by C. J. Hart, of Pueblo, Master of the Grand Lodge of Freemasons of Colorado, and Hon. J. C. Shattuck, State Superintendent of Public Instruction.

The description of the building contains some strong adjectives not inappropriate, perhaps, when the time and conditions are taken into account. The building, 62×43½

feet, is described as "a piece of workmanship unequaled in the State, impressing every one with its beauty, strength, and solidity." The present class-room in zoölogy and the museum connected therewith are declared to make "a magnificent hall the entire length of the building." Those were the days of small things not to be despised. The structure so glowingly described is the rectangular front with tower of the present Main College Building. The contractor's work was supervised by Andrew Armstrong, of Fort Collins.

Considerable space is given in this report to "Fruit in Colorado."

At the time this report was made, no definite action had been taken looking to securing the 90,000 acres of land to which the College was entitled under the congressional land-grant act of 1862, herein elsewhere mentioned. The one-tenth of a mill, then authorized to be levied upon the taxable property of the State for college support, was found inadequate to secure that end properly. Requests for a special appropriation of $3,000 and an increase of the mill tax from one-tenth to one-fifth conclude this report—one of the most important of those issued by the Board.

At this time the total annual receipts of the College, from all sources, was but little more than $7,000.

The minutes of the Board show that a resolution to open the College for the reception and instruction of students on May 1, 1879, was adopted February 26, 1879. A preamble states the resolution to be the outgrowth of a loan by the General Assembly to The State Board of Agriculture to enable it "to open The State Agricultural College for public instruction." It was found inadvisable to open the College in May. Subsequent Board action fixed upon the first Monday in September as the time for beginning scholastic work.

A committee to make inquiries in relation to a suitable person for President of the College, and to report thereafter in regard thereto, was composed of the following-named Board members: J. S. Stanger, P. M. Hinman, and B. S. La Grange. At a meeting of the Board,

held at the College, May 27, 1879, this committee reported in favor of calling Prof. E. E. Edwards, of McKendree College, Lebanon, Illinois, to the presidency of the College at an annual salary of $1,800. The report was unanimously adopted.

President Edwards's first appearance at Board meeting is noted in the minutes under date of June 30, 1879. At this meeting A. E. Blount was elected Professor of Practical Agriculture and Frank J. Annis, Professor of Chemistry. The salaries fixed were $1,200 and $1,000, respectively, per annum.

A circular, embodying a course of study, was prepared by joint action of the Faculty and a committee from the Board—J. S. Stanger and P. M. Hinman. On July 5, 1879, the Board ordered the distribution of 2,000 copies of this circular.

The initial term of the College opened September 1, 1879. The record shows the enrollment of twenty different students at the close of this term. There was but one course of study. The college-year began with the spring term and closed with the autumn term, the vacation season occurring in midwinter. The calendar for 1881-1882 shows the abandonment of this arrangement and the adoption of the present plan of three consecutive terms of thirteen weeks each with a short vacation at Christmas season and a long vacation extending from "Commencement Day," early in June, to the first Monday in September.

Elective studies are first noted in the catalogues for 1886-'87. The next year brings the announcement for the differentiation of the work at the close of the Sophomore year. Two courses, the Agricultural and the Mechanical, are outlined. The Irrigation Engineering Course and the Ladies' Course were first scheduled in the catalogue for 1889-'90.

The reports of the President of the Faculty are important official contributions to college history. The first printed report of President Edwards appears as a part of the Board report for 1880. It covers seventeen pages.

Prof. C. L. Ingersoll, of Purdue University, Indiana, became President of the College, August 1, 1882. The resignation of President Edwards was accepted by the Board at a meeting held April 7, 1882. Prof. A. E. Blount, as senior professor, was Acting President between the dates named. President Ingersoll's first report occupies sixteen pages in the Board report for 1882.

The first report of the President of the College to the State Superintendent of Public Instruction is found in the third biennial report, of the latter officer, for the term ending August 31, 1882. Since that date, every biennial report issued from the State Department of Public Instruction has contained a carefully compiled report, prepared by its President or the officer acting temporarily in his stead, of the work and growth of the College.

The annual catalogues issued from the President's office show the features of college work, generally exhibited in such printed matter, very fully. No study of the growth of the College would be complete without it included a careful examination of these pamphlet publications.

Prior to the establishment of the Experiment Station, under the provisions of the "Hatch Act" of 1887, the annual reports of the Board contained much information regarding agricultural and horticultural work in Colorado. This information came chiefly through the reports of the Secretary of the Board and the Professor of Agriculture.

The publications issued, from time to time, from the Secretary's office and bearing title, "*Agricultural Statistics*," have been compiled under conditions that have made their value a questionable quantity. In his statistical report for 1886, the Secretary says: "Some provision ought to be made whereby certainty and accuracy can be secured in collecting and making these returns." The "provision" so much needed ten years ago has not been made.

In 1886, a pamphlet entitled "Experimental Work of the Horticultural Department" was issued. The author was James Cassidy, Professor of Horticulture. The

subjects treated are herewith named: Experiments with Potatoes; Irrigation in Horticulture; Report on Grasses; Report on Weeds; Report on Forestry; Report on Fruits; Report on Garden Vegetables; Smut on Grass; and Report on Seed Tests. This pamphlet is the worthy forerunner of the bulletin literature regularly issued since the establishment of the College Experiment Station in February, 1888.

The report of the Board for 1880, contains an account of what is believed to be the *first* "Farmers' Institute" held in Colorado. It met in the College Chapel on Wednesday evening November 26, 1879, and was called to order by President Watrous of The State Board of Agriculture. The principal addresses were delivered by President E. E. Edwards on, "The Utility of Tree Culture," and Secretary Harris Stratton on, "Practical Dairying."

Looking over the Board reports for the years 1880, 1881, and 1882, I am forced to believe that the interest of the farmers of Colorado in information and methods bearing upon their work was as strong then as it is now. The prosecution of institute work among the farming communities of our State has not been followed by very gratifying results.

In the years before named, institutes were held in Fort Collins, Del Norte, Greeley, Longmont, Boulder, Loveland, Monument, and Trinidad. Some of the papers and addresses are found in the Board reports. The titles of a few papers, and the names of their authors, are given in this connection:—

Hints to Fruit Growers	J. S. Perkey
Corn and its Culture	A. L. Emigh
Potato Culture	G. W. Buell
Live Stock	A. J. Wilbur
Wheat Culture and Rotation of Crops	Samuel Blodgett
Bee Culture	J. S. Flory
Potato Raising near Longmont	C. C. Calkins
Wheat and its Culture Under-Draining and Reclaiming Alkalied Lands	P. M. Hinman
Flowers: Their Cultivation in the House	Mrs. E. D. Armstrong
Dairy Farming	J. E. Washburn.

Illuminating Oil.............................. Science and Agriculture......................	Chas. F. Davis
Dairying	G. W. Eggleston
Seeds.. Wheat..	A. E. Blount
Culture of Small Fruits........................	A. N. Hoag
Tree Tillers...................................	J. K. Peabody
Horticultural Products of Greeley and Union Colonies.......	A. E. Gibson
Fall *versus* Spring Plowing......................	D. L. Tracy
An Ideal Garden....................	Mrs. Albina L. Washburn
The Home of the Future..................	Mrs. Harris Stratton
Agriculture in Colorado—Irrigation...............	J. S. Stanger

The Board report for 1888 contains papers read before farmers' institutes held in Fort Collins and Loveland. They are as follows:—

Cattle Feeding, A. E. Blount; Horticultural Experimentation for Colorado, James Cassidy; Manual Training, James W. Lawrence; Storage Waters in Reservoirs for Irrigation, Vasa E. Stolbrand; Creameries and Cheese Factories in Colorado, G. Frank Otis; Profits of Poultry, Mrs. W. C. Stiles; and Carp Culture, Jacob Hetzel.

It is not known why the publication of such well-prepared, practical papers, as a part of the annual report of the Board, was discontinued. The reading of some of these papers before farmers' institutes of to-day would not be unproductive of good.

One new feature is seen in the report for 1886. An abstract of the proceedings of the regular annual meeting of the Board, held December 8, 9, and 10, is published. This is the only instance of such publication in the history of the Board, as far as I can determine.

Many other matters of interest connected with college history might be referred to in this connection; but their mention might be considered, by some, an unnecessary lengthening of this report. The importance of such historical data will be more recognized as the College advances in its now clearly outlined path of prosperity. The days of infant struggle will be looked back to with keener appreciation as they recede farther into the past. Many of those who aided the establishment and early

growth of the institution, by their wisely-planned, self-sacrificing efforts, are yet with us and are in position to give us much interesting information not as yet a matter of record. The opportunity for securing this information and making it available for the use of the future historian should not be permitted to go by. Now is the opportune time for the collection and compilation of the data essential for the preparation of an authentic history of the College during its initial and formative periods.

THE NATIONAL GOVERNMENT AND THE COLLEGE.

The General Government is a financial backer of the College under the terms of the "Morrill Bills" of July 2, 1862, and August 30, 1890. No inconsiderable portion of college revenue is now derived from the operation of these congressional acts. The present flourishing condition of the College is, in large part, the outgrowth of endowments and appropriations made by Congress. The provisions of the second bill are more liberal to the smaller states of the Union than are those of its forerunner.

The act of 1862 made a donation of public lands to the several states and territories in order to "provide colleges for the benefit of agriculture and mechanic arts." The land was apportioned among the beneficiaries, under the act, so that each state received thirty thousand acres for each Senator and Representative it had in Congress. By this method of distribution, the older and more populous states received the greatest benefit from the endowment. New York and Colorado do not stand on an equal footing to-day when measuring revenues derived from the land-grant act of 1862. In some states, the present annual revenue received under the provisions of the first "Morrill Bill" amounts to many thousands of dollars.

There was some delay, on the part of the proper authorities in Colorado, in securing to the State the advantages of the congressional legislation of 1862. The General Assembly of Colorado, by act bearing date January 27, 1879, gave assent to this congressional act and

accepted it with all the provisions connected therewith. These provisions are clearly stated and relate, principally, to the selection of the land and the disposal to be made of the money derived from its sale. It is provided that the fund secured from land sales shall be kept unimpaired and that all losses connected with its handling shall be made good by the state concerned. The clear intention of the act is that only the revenue secured from the original endowment shall be used in support of the institution contemplated, and that support not to extend to the erection or repair of any building.

A portion of section 4, of this act of 1862, has been often quoted. It clearly outlines the nature of the work to be put in operation by the college "for the benefit of agriculture and mechanic arts." Its terms furnish the chart whereby the course of instruction can be traced. Of the liberality of those terms the language of said section, is the best testimony: "The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the states may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

Under the terms of this act, Colorado received 90,000 acres of land. The management and control of this land are vested in the State Board of Land Commissioners. The college authorities have nothing to do with its sale or other disposition. I venture to say that the revenue for college support derived from the land-grant act of 1862, is as unknowable a quantity to the members of The State Board of Agriculture as any whose expenditure is controlled by them. Some knowledge of a thing is a condition precedent to any great interest in it. In many states, the land-grant endowment is under the control of the college governing board, both before and after it becomes productive of revenue. In some states, the income from land sales and rentals is used to liquidate a portion of state indebtedness. Then the total sum thus

used is made a part of the state's irreducible debt, and such part thereof draws interest—not less than 5% per annum, usually payable semi-annually—which goes to give the college an income certain in amount and definite as to the time of its availability for use.

Our land-income fund is not large; and there is no prospect that it will ever be large enough to meet any considerable part of the cost of college maintenance.

All the land donated by congress for the endowment of The State Agricultural College has been located and its location confirmed. I have not the data at hand to set forth clearly how much of this land remains unsold or to make an intelligent estimate of its money value. I am informed that the interest on warrants invested for 1895-'96 amounted to $4,755.66. The State Board of Land Commissioners estimates that the income fund for the year 1897-'98 will be about $3,000. A safe and conservative estimate of next year's college revenue from the congressional land-grant act of 1862, would not make a total in excess of $6,000.

The second "Morrill Bill"—that of August 30, 1890—is designed more completely to endow the colleges of agriculture and mechanic arts established upon the conditions named in the former bill—by the same author—of 1862. Its provisions are of a broader and more liberal nature than those of its predecessor. The states and territories, under its terms, share equally in the government bounty. The sum of fifteen thousand dollars is given, the first year, to each college in whose behalf the additional endowment is made; thereafter the annual increase of said endowment is to be one thousand dollars until a total appropriation of twenty-five thousand dollars annually is reached.

It is now the practice to pay this appropriation in advance on or before July 31 of each year. Unless a change is made in the law, the College will receive its first maximum appropriation of twenty-five thousand dollars in the summer of 1899.

Some of the conditions that hedged about the expenditure of the land-grant fund provided for by the act of 1862 are incorporated in the act of 1890. There is a

proviso that the state, or territory, making acceptance of the endowment, authorized by the act, shall replace any part of it lost or misapplied under penalty of forfeiting all participation thereafter in its benefits. No part of the annual appropriation can be used for building or repair purposes, but the whole thereof must be "applied only to instruction in agriculture, the mechanic arts, the English language, and the various branches of mathematical, natural, and economic science, with special reference to their applications to the industries of life, and to the facilities for such instruction."

By the terms of the two acts herein described, the General Government has become the direct promoter of a phase of public education new in its make-up and far-reaching in its results. An impulse has been given to the idea of a better planned, and more practical education for that large number of our people who gain a livelihood by manual labor.

Our State, by its acceptance of the conditions imposed by the language of these acts, has attested its belief in the efficacy and necessity of the kind of instruction they were designed to foster and pledged itself to be a faithful ally of the General Government is making that instruction as thorough and far-reaching as conditions at hand, and created, will permit.

THE STATE AND THE COLLEGE.

Under the Constitution of Colorado, the Agricultural College became a State institution in 1876. The location of the College and all bequests previously made for its use were confirmed by a provision of that instrument.

By legislative action, taken about the middle of the session of 1877, "The State Board of Agriculture" was created. The first meeting of this Board has been referred to elsewhere. The Board owes its existence and powers to legislative enactments. Those powers are such as are usually exercised by a governing board of an educational institution.

The principal source of state revenue for college support has ever been the "*mill tax*." This tax dates

back to an act of the General Assembly, passed March 9, 1877, by which a tenth-mill levy on all the taxable property of the State was ordered for college use. By act of February 3, 1879, the state levy for use of the College was made one-fifth of a mill. This act was reaffirmed, February 8, 1881, and is now in force.

The bill, approved March 17, 1891, that made provision for a special tax of one-sixth mill, in each instance, for the support and maintenance of certain state educational institutions, The State Agricultural College being of the number, was, in the spring of 1895, declared unconstitutional by the Supreme Court of the State.

Twice has the College suffered a loss of a portion of the mill-tax support provided by law. By action of the Supreme Court in the fall of 1894, the mill-tax levy was made three-twentieths instead of one-sixth. In the fall of 1895, the State Board of Equalization, fearing the tax receipts would be insufficient to sustain the different branches of the state government, as required by law, reduced the college mill-tax from one-fifth to one-sixth. Between the times of the acts of the Supreme Court and the State Board of Equalization, herein mentioned, the unconstitutionality of the act of March 17, 1891, was announced.

By the reduction of the mill tax, twice made as stated, the College suffered a loss of revenue amounting to more than $10,000. This loss of revenue was unexpected—perhaps without justification—and delayed the completion of a college building in course of erection when it occurred.

The Legislature, in addition to providing for the support of the College by the mill tax, before named, has made the following-named special appropriations:—

Year.	Amount.	For What Purpose.
1881	$ 5,000	College Dormitory
1883	10,000	Mechanic Shop
1889	18,000	Extension of Main Building
1893	6,500	Sewer System
1895	10,000	Additions to Buildings

Total of all special appropriations, $49,500.

Taking into consideration the fact that the General Government has, with some liberality, endowed the College, the State has given it fair financial support—as much possibly as the state of its finances would well warrant.

The State undertook a big educational work when it planned for a liberal course of instruction in so many higher institutions of learning. The plan of state institutional management, as far as it concerns educational work in its higher forms, has been so far prosecuted that any effective modification of it looking to a consolidation of institutions at one point and under one authority would be attended, at the outset at least, with serious financial loss, incurred with no strong assurance of a betterment of the educational work now planned and in execution.

It may well be doubted whether a consolidation of all the work of higher education, now in successful operation in the various state institutions of learning, under one management would prove either economical or desirable. An agricultural or a technical school has not much in common, either in work or sentiment, with a university. The work of a normal school can not be made to articulate very closely with that of a school in which students are prepared to become mine engineers.

Consolidation of the state's higher institutions of learning is impossible without a constitutional amendment. It is *theory* that asserts that a saving of revenue would follow such consolidation; and it is *theory* that affirms that the interests of higher education would be promoted thereby. A union of the state's higher educational forces might save something in the way of buildings and equipment, lessen the force of instructors, and decrease the number of governing boards; but, perhaps, these are not results greatly to be desired.

The chief objection to the present status of higher education, as fostered by the State, is that it puts some unnecessary tax burden upon the people. The state levy for all purposes can not exceed four mills on the dollar of taxable property. Less than one-fourth of the total

HORTICULTURAL BUILDING.

tax collected by the State goes to the support of the five institutions now engaged in educational work under its authority.

In many localities in Colorado, the tax-payer pays from fifty to eighty dollars in local taxes to every dollar the State takes from him for the maintenance of *all* these institutions. For instance: when a citizens of Fort Collins, pays $52 into the treasury of Larimer county, one-thirteenth of it, or $4, will find its way to the state treasury; and of that $4, only *twenty cents* will be placed to the credit of The State Agricultural College.

Our State can well afford to give *one mill*, upon the low assessed valuation of its property, for the support of higher education as now fostered in its five institutions of learning. It is the honest belief of many intelligent citizens that the State has received more real benefit from the money spent in support of these institutions than from an equal expenditure *for any other purpose or purposes.*

All these institutions have made gratifying progress under the conditions that have brought other enterprises to a standstill or to ruin. They have felt the restrictions of a decreased revenue at the very time when their rapid increase of students made urgent call for more ample quarters and increased equipments. During this period of struggle and victory, their revenue has been looked upon by greedy eyes and its permanency threatened.

A little less than four years ago, at a time when our student roll was lengthening rapidly, a bill was introduced into the General Assembly to reduce our mill tax from one-sixth to one-tenth mill. This bill took the usual legislative course and met its first obstruction in committee room where representatives of the College secured a hearing. It required some effort on the part of these representatives to secure the defeat of this bill so fraught with mischief to college interests.

While this effort to cut off nearly one-half of our mill tax was under way, the assessed valuation of property in the State was undergoing a rapid decrease. The assessable property in Colorado fell in listed value about

$30,000,000 between the spring of 1893 and that of 1894. It makes one interested in the growth of the College tremble with apprehension when he sees but a few votes stand between it and financial ruin.

Some *definite* revenue is a requisite for any business-like management of the College. A wise business man tries to look ahead and to arrange for what he desires to bring about. If one has no plans, if he is simply living from hand to mouth, it does not much matter what conditions confront him, now or hereafter. No one can tell how to cut a garment until he knows how much cloth he can secure; no institutional management can look beyond its nose until its vision is strengthened by a steady light.

I look with misgiving that some business sense awakens upon the plan that has been proposed of abolishing the mill tax for the support of the state educational institutions. The carrying out of that plan means the placing of the institution upon an uncertain and insecure financial basis. Under such a condition of financial chaos, no intelligent effort could project itself far into the future. The proposition is suggestive of a management without stability, force, or efficiency. A precarious revenue would tie the hands and hold back the energies of every one working in any manner for the upbuilding of the educational institutions of the State.

Then, too, all business experience protests against the abandonment of the present system of providing for institutional maintenance. No enterprise of any moment should be entered upon before ways and means for its intelligent prosecution have been wisely considered and adequately provided. The most disagreeable feature connected with the management of the educational institutions of our State is the necessity that forces those in control of them to make application to the General Assembly for *special* appropriations. Added to this loss of time and energy, which under more satisfactory conditions could be better expended elsewhere, is the fear, forcing to active effort, that ill-advised legislation may sweep away, in a day, the little fund made, as it were,

an endowment by past legislative wisdom. The thought and activity so much needed to promote work *within* the institutions, and make known its scope and value to those who might be induced thereby to avail themselves of its advantages, are weakened by the necessity of lobbying efforts to hold appropriated revenue and to secure much needed additions thereto.

A *certain* mill-tax revenue should need no advocacy before those who are really desirous of promoting the growth of the state's educational institutions. The signboard of experience points unerringly to the kind of business management these institutions should be under to put them in a favorable condition for accomplishing, with good result, the purpose for which they were established. Give them a *certain* revenue, as liberal in amount as all considerations and conditions make advisable; place them under the control of boards whose membership has been judiciously selected; and then free them from threats of unwise legislative interference. Under such a policy every educational institution in the State would feel the thrill of a new life and a more energized purpose.

The good results of past effort, now so apparent, indicate the surest means by which future prosperity can be assured. Frequent legislative interference with the revenue or management of these institutions is a menace to their well-being. Former legislative acts relating to them have followed the best practice in other states. The tendency of legislation, almost everywhere, is to place a state's educational institutions on a sure and liberal financial basis. Let not ill-advised legislation push us many steps backward in our country's advancing educational column.

Again, it is not in the line of sound policy for our lawmakers to attempt a sort of personal control over the internal management of these institutions. Our Legislature meets biennially. Its membership is subject to frequent changes. From the nature of things it is impossible for its members to have any great familiarity with the workings of the educational institutions of the State. Any attempt by them to restrict the governing

boards of these institutions in the exercise of the duties usually devolving upon such bodies will likely be more productive of harm than good.

One hundred lawmakers, meeting biennially in 90-day session, do not form a body best fitted to control the internal workings of an institution which many of them have never seen. It is hardly possible that such a body can legislate aright except in a general way, upon such matters.

The boards in immediate control of our state institutions are the bodies best fitted, by experience and contact, to supervise their special workings. The members of these local boards are under official oath, are appointed for an extended period of service, and, in the performance of their official duties, are brought in frequent contact with the work it is their proper province to have organized and prosecuted. They have better knowledge of what it most calculated to promote the growth of the institution under their control than any legislative body can possibly have.

Three proposed acts of legislation that have advocates and which, in my opinion, would, if made operative, prove hurtful to the interests of our institution, and others as well, are as follows:—

1. To place the management of all the state educational institutions under one board of control.

2. To repeal all laws making annual mill-tax levies for the support of said institutions, and thus require their management to depend upon legislative lobbying for their financial support.

3. Arbitrarily to fix, without reference to work done or fitness to perform it, the salaries of certain employes connected with the executive departments of said educational institutions.

In reference to the last-named measure, it may well be affirmed that the local governing board of each institution, by reason of its direct knowledge of the work connected therewith, is the proper and logical power finally to determine the value of the service rendered by any employe under its authority, whether in the executive office or the janitor's quarters.

COLLEGE REVENUE—EXPENSES.

An educational institution is not designed to be a "savings bank." It is expected that its management will make use of all money that comes into its hand in promoting its growth and widening its sphere of usefulness. There should be no *waste* either of money or educational force. There are many well-endowed institutions of learning in the country whose large revenue is expended almost as fast as it is received; and no sound principle of finance is violated by that course. It is the duty of an educational board to spend all the revenue within its reach, but the expenditure must be so directed as to secure worthy and legitimate results.

In the history of the College, thus far, the governing board has never been troubled with a surplus in the college treasury. The all-absorbing, ever-present question has been how to keep expenditures of most pressing necessity within the estimated receipts.

Our sources of revenue have been reported frequently. Herewith is presented an estimate of the income of the College—from all sources—for the fiscal year ending November 30, 1897:—

1. Land Income Fund, derived from interest on money received from sales of land donated by the General Government, and rents of leased lands not yet sold, (Morrill Bill of July 2, 1862), about $5,000.

2. Government appropriation for the support of the Experiment Station, (Hatch Act of March 2, 1887), $15,000.

3. United States Fund, (Morrill Bill of August 30, 1890), $23,000.

4. State Tax Fund, one-fifth of a mill on all the taxable property of the State, about $40,000.

Yearly receipts from all sources, given approximately, $83,000.

Had the college revenue from the mill tax for 1895 and 1896, been received as per statutory provision, the college finances would now be in good condition. The loss of that expected revenue has disarranged plans look-

ing to certain permanent improvements and seriously delayed others in progress when it was first announced.

There is a "*special fund*" reported in connection with college finances that is only referred to here to show that by it the sum total of money receipts is swelled without any real increase in college revenue. Books for student use are bought with college funds and placed on sale. The sales about balance the original cost, and the money thus derived finds its way into the "*special fund.*" This fund is also added to by sales of college products or supplies made by one department to another. The money for anything sold, though it may have cost the College its selling price, or more, helps augment the "special fund."

Under proper conditions the revenue for college support would be fairly adequate. With the present one-fifth mill tax, levied on a lawful valuation of assessable property, and with the financial support derived from the General Government, necessary current expenditures could be met. An occasional special appropriation for *building purposes* would then be the extent of college demands upon the treasury of the State.

The assessed value of taxable property in Colorado, for the last five years, is herewith given:—

1892	$236,884,449.48
1893	238,722,417.05
1894	208,905,379.15
1895	201,308,969.10
1896	206,598,561.00

Future wants of the College will undoubtedly be in excess of present ones. Our revenue for college support must increase with the demands made urgent by the presence of a much larger number of students. If property valuation increases, the mill tax on such valuation, provided legislative interference does not occur, will give the College ample financial backing.

There are expenses connected with college management that can be pretty definitely determined in advance. The salary roll is now as follows: College fund, $37,620; Station fund, $12,000; Total $49,620. In December 1895,

the Board, upon recommendation of its Committee on Finance, made an appropriation of $22,580 for current expenses and support of the various departments of instruction, including the library. The sum last named did not include any appropriation from the Experiment Station Fund. Subsequent action provided for the distribution of any money to the credit of this fund after salary payments had been made. Additions to the teaching force must be made in the near future. Some of the classes are too large and must be divided. Each year brings some necessary expenditures that were not expected when appropriations for current expenses were made. A conservative estimate of the total disbursement for the coming fiscal year—including salaries, current expenses connected with the College, and maintenance expenses of the Experiment Station—is a total of $80,000. It will be seen that this estimate includes no expense connected with the building, and equipment, of the new Chemical Laboratory.

PAY-ROLL AND INVENTORIES.

The increase of the salary roll within the year, covered by this report, is $1,020, or a little more than *two per cent.* The student enrollment within the same period has increased more than *forty per cent.*

The inventories were made out early in November. Great care was taken to secure close valuations. There is an increase, amounting to $5,287.69, in the total valuation of college property.

The following statistics are appropriately given in this connection.

THE STATE AGRICULTURAL COLLEGE.

FORT COLLINS, COLORADO.

November 30, 1896.

NAMES OF INSTRUCTORS AND REGULAR EMPLOYES, WITH THEIR ANNUAL SALARIES; ALSO A STATEMENT OF THE FUND OR FUNDS WHENCE SUCH SALARIES ARE DRAWN.

	College Fund.	Station Fund.
Faculty—		
Alston Ellis	$ 5,000.00	$ 1,000.00
James W. Lawrence	2,000.00	....
Maud Bell	1,500.00	....
Louis G. Carpenter	1,500.00	500.00
Charles S. Crandall	1,500.00	500.00
Clarence P. Gillette	1,500.00	500.00
Grace Espy Patton	1,500.00	....
William J. Meyers	1,500.00	....
Daniel W. Working	800.00	400.00
Wells W. Cooke	1,500.00	500.00
William P. Headden	1,500.00	500.00
Harry D. Humphrey, (U. S. A.)	....	....
Theodosia G. Ammons	1,500.00	....
Jacob A. Christman	1,100.00	....
Stenographer—		
Lathrop M. Taylor	900.00	....
Librarian—		
Marguerite E. Stratton	600.00	....
Instructors—		
Corydon A. Woody	1,000.00	....
Edward M. Traber	900.00	....
Edward B. House	900.00	....
Assistants—		
Jay D. Stannard	1,000.00	....
L. D. Crain	1,000.00	....
Frank L. Watrous	....	1,000.00
Jacob H. Cowen	....	1,000.00
Charles J. Ryan	....	900.00
Robert E. Trimble	....	900.00
Emma A. Gillette	....	300.00
Allen P. Greenacre	600.00	....
William Garbe	540.00	....
Charles F. Mergelman	780.00	....

	College Fund.	Station Fund.
Sub-Station Superintendents—		
Philo K. Blinn	....	800.00
Charles A. Duncan	....	....
J. E. Payne	....	600.00
Engineers and Janitors—		
William Kelly	780.00	....
John H. Cameron, Sr	600.00	....
James L. Veazey	540.00	....
A. M. Wilkin	540.00	....
Laborers Regularly Employed—		
N. G. Strayer	540.00	....
Frank Mathews	540.00	....
J. E. Kiteley	540.00	....
Robert Cameron	480.00	....
Alvin Fry	540.00	....
John H. Cameron, Jr	540.00	....
Total	$ 36,260.00	$ 9,400.00
General Labor—		
Station Labor	$	$ 2,600.00
College Labor	660.00	....
Student Labor	700.00	....
Total	$ 1,360.00	$ 2,600.00

SUMMARY.

	College Fund.	Station Fund.
Salaries	$ 36,260.00	$ 9,400.00
Labor	1,360.00	2,600.00
Grand Total	$ 37,620.00	$ 12,000.00

SUMMARY OF COLLEGE INVENTORIES.

NOVEMBER 30, 1896.

LANDS AND ADJUNCTS—

Two hundred and forty (240) acres of land at one hundred dollars ($100) per acre	$ 24,000.00	
Trunk sewer and pipe-line for water supply	8,900.00	
		*$ 32,900.00

*This estimate includes numerous sewer laterals and water connections; a reservoir for storage of water; all other improvements on the college grounds; and ditch stock worth $2,000.

BUILDINGS AND PERMANENT FIXTURES—

Main College Building	$ 36,000.00	
Mechanical Engineering Building	21,000.00	
Agricultural Building and Creamery	10,500.00	
Horticultural Building	15,100.00	
Civil Engineering Building	9,000.00	
Chemical Laboratory	5,000.00	
Building for Department of Domestic Economy	4,650.00	
Greenhouses	4,500.00	
Other buildings on the College Grounds	12,625.00	
		$ 118,375.00

DEPARTMENT INVENTORIES—

History and Literature	$ 357.00	
English and Sociology	166.50	
Mathematics	568.60	
Military Science	5,321.00	
Physiology, Zoology, and Entomology	5,414.31	
Mechanical Engineering and Drawing	9,572.90	
Agriculture	4,781.75	
Horticulture	6,231.51	
Civil Engineering and Physics	9,448.89	
Chemistry	1,646.83	
Domestic Economy	657.73	
Commercial Department	847.19	
		$ 45,014.21

MISCELLANEOUS—

President's Office No. 1	$ 2,891.73	
President's Office No. 2	2,375.50	
Secretary's Office	579.08	
Director's Office	875.00	
Library	9,689.00	
		$ 16,410.31
Grand Total for College		$ 212,699.52

MISCELLANEOUS—Continued.

Total value of College property, 1891, $144,568.98.
Total value of College property, 1892, $176,600.26.
Total value of College property, 1893, $187,847.53.
Total value of College property, 1894, $197,633.76,
Total value of College property, 1895, $207,411.83.
Total value of College property, 1896, $212,699.52.

EXPERIMENT STATION INVENTORIES.

NOVEMBER 30, 1896.

AGRICULTURAL SECTION, FORT COLLINS—		
Farm Implements.....$	677.10	
Seed Grain.....	84.00	
		$ 761.10
HORTICULTURAL SECTION, FORT COLLINS—		
Instruments .....$	143.95	
Supplies	530.94	
		$ 674.89
SECTION OF IRRIGATION AND METEOROLOGY, FORT COLLINS—		
Meteorological Instruments.....$	531.35	
Irrigation Apparatus.....	219.65	
Photographic Apparatus.....	110.58	
Hydraulic Apparatus.....	94.60	
Stationery, Books, and Maps.....	17.66	
Miscellaneous	73.85	
		$ 1,047.69
ENTOMOLOGICAL SECTION, FORT COLLINS—		
Laboratory Supplies.....$	83.95	
Entomological Supplies.....	47.55	
Insecticides and Apparatus.....	117.65	
Apiary Supplies.....	149.20	
Microscopical Apparatus.....	335.00	
		$ 733.35
Total for Home Station.....		$ 3,217.03

ARKANSAS VALLEY STATION, ROCKY FORD—		
Two hundred (200) acres of land......$	8,600.00	
Water Rights and Apparatus	1,873.00	
Buildings and Fencing	2,326.00	
Live Stock	346.00	
Farm Implements	590.20	
Farm Products on Hand	701.46	
		$ 14,436.66
SAN LUIS VALLEY STATION, MONTE VISTA—		
One hundred and sixty (160) acres of land......$	2,110.00	
Twenty (20) inches water in Rio Grande Canal.	300.00	
Buildings, Fencing, and Well	1,497.00	
Horses, Wagon, and Harness	205.00	
Farm Implements	170.15	
Farm Products on Hand	46.70	
Nine (9) Berkshire Hogs	135.00	
		$ 4,463.85
DIVIDE STATION, MONUMENT—		
Forty (40) acres of land......$	200.00	
Buildings	800.00	
		$ 1,000.00
RAIN-BELT STATION, CHEYENNE WELLS—		
One hundred and sixty (160) acres of land......$	220.00	
House, Barn, and Fencing	1,565.00	
Horses, Wagon, and Harness	130.00	
Farm Implements	165.38	
Farm Products and Supplies on Hand	91.70	
		$ 2,172.08
Total Sub-Station Property......$		22,072.59

Grand Total Experiment Station Property, 1896, $25,289.62.

Grand Total Experiment Station Property, 1895, $27,086.78.

Grand Total Experiment Station Property, 1894, $29,797.18.

Grand Total Experiment Station Property, 1893, $25,037.12.

PERMANENT IMPROVEMENTS.

Few improvements to the college grounds have been made within the year. In fact they were not needed. The

land upon which the operations of the agricultural and horticultural departments are conducted is always in a sightly condition. The college campus—that portion of the grounds upon which the college buildings are located —is made very attractive looking, particularly in the summer season, by the skill and energy of the florist. The manner in which our grounds are kept reflects credit upon those whose duty it is to oversee them.

The special 10,000-dollar appropriation, made by the State Legislature in the spring of 1895, for permanently improving the real property of the College, was not available for that purpose until the summer of 1896. The whole of that appropriation has been spent to the best advantage.

The permanent improvements made within the year now closing are herewith summarized:

Stone floor in the basement of the Main Building..$	100.00	
Additional plumbing in the Domestic Economy Building	225.00	
Remodeling the College Barn	450.00	
Greenhouses adjoining the Horticultural Building.	2,788.00	
Stone floor in the Forge Room of the Mechanical Engineering Building	141.00	
Additional heating apparatus in Mechanical Engineering Building	419.00	
Additions to Mechanical Engineering Building	4,728.00	
New Chemical Building (partly estimated)	2,500.00	
Total		$ 11,351.00

The total of all sums expended in permanent improvements, for the two years ending November 30, 1896, is $18,721.

Something relating to these permanent improvements, more in detail, may have interest to some. The stone paving in the Main Building was laid in the basement hall, leading to the Armory, which before was a mass of patch work. The plumbing work in the Domestic Economy Building was a rearrangement of the hot-water pipes and the putting in place of bath-tubs for the use of the women. The iron roof of the barn has been re-

placed by shingles and the general appearance of the building much improved by the addition of a cupola and two large dormer windows.

Other improvements on the College Farm, not before mentioned because their cost was met from the department appropriation, are changes in the basement of the barn better to adapt it for use of stock; pens and sheds for sheep used in feeding experiments; and pens for the accommodation of a large number of pigs. These extra improvements cost about $350.

The new greenhouse recently completed is one wing of a plan which contemplates the addition, at some future time, of a palm-house, and a second wing similar to the one built. Its construction is such that the other parts can be added at any time.

The structure is 25×50 feet and consists of a wrought-iron frame securely bolted to cast sills which cap, and are supported by, brick walls rising from a stone foundation. The frame carries the heating pipes and also the shafting from the self-locking ventilating machines. The glazing strips are of clear Gulf cypress, fitted to special castings at either end, and firmly fastened to iron purlins. The house is provided with non-freezing gutters and is glazed with the best greenhouse glass. The benches are of iron, with porous tile bottoms and cypress sides. Two lines of sash at the sides, and two at the ridge are connected with geared machines which give perfect control over ventilation.

The frame of the house possesses strength, and at the same time offers little obstruction to light. In plan and details the structure is modern; embracing the best that is known in greenhouse construction. It was purchased of the Lord & Burnham Company, of New York City.

In addition to this greenhouse there has been added a forcing-house, 20×50 feet, made of cypress frame resting upon brick walls, and a glass connection between the forcing-house and the laboratory which is 14×14 feet. In this latter house the sides are carried perpendicular to the height of nine feet, affording space for tall plants.

The main portion of the Mechanical Engineering Building was increased by an addition running westward a distance of 70 feet. The addition is two stories high, with an attic for storing lumber and other supplies. On the ground floor, at the west end, is a well-lighted class-room. This class-room is supplied with models and drawings for illustrating the work in mechanical engineering.

The remaining part of the addition unites with the older part of the building thus forming the machine room. The entire second floor is used by the wood-working classes. Here have been put in place twenty new wood-working benches, each with its complete set of tools. There is accommodation here for forty-five students at one time. The forge room has been enlarged and its floor covered with stone flagging. It is now 46×35 feet and gives ample space for twenty-five workers. The latest overhead system of the Buffalo Forge Company is used. The foundry improvements consist of new moulding benches, with cast-iron brackets, conveniently arranged. Twenty adjustable tables for use in freehand drawing and fifty individual tables for use in mechanical drawing have been placed in the draughting room.

CHEMICAL LABORATORY.

The need of a better building for the use of the Chemical Department has long been recognized. The building in which the chemical work of the College and Station is now done is one of the oldest on the college grounds. It could not be put in proper shape to meet the present wants of the department.

Under the head of "Needed Improvements," the Committee on College Buildings and Permanent Improvements, in a report to the Board, June 5, 1896, said: "First and foremost among these is probably a chemical laboratory." * * "It is, therefore, recommended by your committee that plans be drawn, and contract let, for a chemical laboratory on a scale commensurate with the needs of the Chemical Department." The report from which these extracts are taken was signed by A. L. Emigh and J. E. Du Bois.

After the unanimous adoption of the report, the location of the proposed building was fixed at a point south of the Main Building. Then, the same committee was instructed to secure plans and specifications for the building and to have the same ready for board consideration in a special meeting to be called for that purpose.

The special meeting was held July 30, 1896. Architects Harlan Thomas and Richard Phillips, of Denver, were present and, upon request, presented their plans for the new building and explained them at some length.

Mr. Thomas's plans were accepted, after which the following preamble and resolutions were unanimously adopted:

WHEREAS, The Board has adopted the general plans for a Chemical Laboratory presented by Harlan Thomas, Architect; therefore,

Resolved, That the Committee on College Buildings and Permanent Improvements be, and the same is hereby, instructed to secure from said Thomas detailed drawings and specifications for said Chemical Laboratory, and that thereafter said committee shall advertise for bids for the construction of the building in conformity with said plans and specifications.

Resolved, further, That said committee shall have power to accept the lowest and best bid for the construction of the building and shall have power to arrange for its proper supervision when in course of construction; and be it further

Resolved, That said committee shall so arrange the terms with the successful bidder, or contractor, that the payments shall not be completed prior to September 1st, 1897, and that not to exceed $6,000 of the total contract price for the erection of said building shall become due and payable before April 1st, 1897.

Resolved, finally, That it is the purpose and intent of the foregoing resolutions, except in the cases specified, to confer upon the Committee on College Buildings and Permanent Improvements full authority and power to proceed as soon as practicable with the construction of said Chemical Laboratory and to control the work on the same until its completion, and acceptance by this Board.

By readjustment of the Board committees, made necessary by resignations and the election of new members, the committee referred to in the resolutions quoted

MECHANICAL ENGINEERING BUILDING.

was as follows: James E. Du Bois, Alston Ellis, and A. S. Benson. The Committee received the following bids on September 23, 1896:—

Names of Bidders.	Total Price.	Carpenter Work.	Stone Work.
J. C. Working	$ 22,980.00	$ 11,550.00	$ ....
Hiram Pierce (a)	21,000.00	10,300.00	....
John G. Lunn	21,200.00	....	....
Philip Funke	21,323.00	11,138.00	....
W. J. Hill	20,745.00	9,994.00	....
Brown & Schrepferman (b)	22,084.00	11,799.00	....
Frank Anderson (c)	20,400.00	....	....
E. Ackroyd & Company	....	....	11,750.00
William Metcalf	....	....	10,285.00

(a) Wiring excepted. (b) With cement, $375 extra. (c) With cement, $46 extra.

The contract was awarded to Frank Anderson, of Denver, at his bid as before stated. The contractor entered into bond with the committee, acting in the name and by the authority of The State Board of Agriculture, in the sum of ten thousand dollars ($10,000), conditioned on the faithful performance of all work in conformity with the plans and specifications, which were made a part of the contract. The sureties on the bond, aforesaid, are C. D. McPhee and J. J. McGinnity, both of Denver. Ground was broken Wednesday, October 14, 1896, and the work of excavating was pushed rapidly.

The ground about the college buildings is not the best upon which to erect heavy structures. It was found, when the depth designated in the plans was reached, that the character of the earth gave doubt as to its fitness securely to sustain the weight of the building. After careful investigation it was decided to put all doubt aside by sinking the foundation to a greater depth. An addition to the original contract clearly specifies the nature and amount of the added work and the amount to be paid therefor. The stronger and deeper foundation, deemed to be advisable, will add about $1,000 to the cost of the building.

For the brief description of the building herewith given, I am indebted to the architect: This new laboratory building is designed after the French Renaissance style of architecture, with the individual grace and picturesque effect of the old French chateaux. It appears in pleasing contrast with the Romanesque structures in the midst of which it is erected. It is constructed of red sandstone rubbed and smoothed. In the interior arrangement, convenience and facility for carrying on efficient chemical analysis are kept in mind.

To the left of the main loggia, on the first floor, is the professor's suite of rooms, including office, balance room, and private laboratory—the latter being provided with hoods and direct communication with a storage room in the basement.

To the right, the stairway leads to an entrance on the second floor. Here are the assistant's quarters—office; experiment station laboratory, with balance room and hoods; storage room; and nitrogen room containing two hoods.

Directly in front of the main entrance to the loggia, is the qualitative laboratory, 30×38 feet, supplied with working desks large enough to accommodate thirty-two students. This room is provided with nine hoods, storage room, and balance room. This room being an inside room, is lighted by a large skylight in the roof—a superior system of lighting when the work to be done is considered.

To the left of this laboratory, and behind the professor's rooms, is the quantitative laboratory arranged to accommodate twelve students. It is furnished with six laboratory desks, two hoods, and a balance room.

All laboratory desks throughout the building are made of quarter-sawed oak tops and butternut sides, doors, drawers, etc. The sinks are placed at the sides of the laboratories. Each desk is provided with gas and water supplies; also a 2-inch waste, flush with the top of the desk and supplied with a rubber plug. This waste takes the place of sinks in the desk and eliminates much uncleanness usually connected with the work. The hoods

are furnished with gas and water supplies; also with strong draft accelerated by hot-water coils placed in large vent stacks.

The second floor of the building is arranged into two lecture rooms, each about 26×46 feet. The chemistry lecture room is connected with the apparatus room by a large hood, provided with slides on both sides, making the transfer of apparatus rapid and convenient. There is connection, also, with the museum and chemical cabinet. The geology lecture room is connected with microscopical room and the museum. The basement is used principally for storage and heating purposes, gas generation, and some analytical work.

LIBRARY.

I quote what I said recently in my report to the State Superintendent of Public Instruction and make some addition thereto:—

A valuable means of general culture is found in the library, whose large and well-selected stock of books is within reach of students at all seasonable times of the year. The sum spent in support of the library, exclusive of the librarian's salary, within the last year, is not less than $3,500. Through the painstaking effort of the Faculty Committee on Library, the book purchases have brought to the library shelves a large number of choice and standard works at a very reasonable cost. The number of periodicals has been judiciously increased. New shelving to furnish room for the large increase of books has been put in place and a basement room fitted up for the same purpose. Available space for a further extension of library accommodations is not to be had in any of the present college buildings. These are already occupied from basement to garret by departmental classes and equipment. A library building is a need that all recognize who have occasion to use or inspect the cramped quarters in which the library is now housed. The growth of the library in the number of bound volumes is shown in the following tabular statement. The year 1891 is

made the starting-point, at which time the library contained 3,246 volumes:—

1891. Total volumes	3,246
1892. Accessions	887
1893. Accessions	162
1894. Accessions	178
1895. Accessions	763
1896. Accessions	3,363
Total bound volumes November 30, 1896	8,599

There are probably 10,000 pamphlets, of more or less value, belonging to the library. It is hoped that some means will be found for binding the most valuable of these and thus make the information they contain accessible and serviceable.

The Dewey Decimal System of classification is used. The books are divided into ten general classes, as follows:—

000. General works (periodicals, encyclopedias, etc.).
100. Philosophy.
200. Religion.
300. Sociology.
400. Philology.
500. Natural Science.
600. Useful Arts.
700. Fine Arts.
800. Literature.
900. History, including biography, and travels.

These ten classes are divided and subdivided to an extent needed in a general library.

Good order in the library is preserved at all times. This is not a matter of difficulty, but it absorbs much of the librarian's time and retards the proper handling of the large number of books purchased within the year. When the work of cataloguing, now under way, is completed the matter of finding any book in the library will be attended with no difficulty or delay.

COLLEGE TEXT-BOOKS.

Text-books, drawing material, and some stationery are sold, to students, under college authority. This is no

"money-making scheme" by which students are forced to add to the college revenue. On the contrary, the plan of text-book supply now in operation requires careful oversight to save the College financial loss.

A careful estimate of the books and supplies needed for student use is prepared. Purchases are then made from the publishers, or wholesale houses, on the best terms securable for cash. The selling price for all supplies to be furnished students is reached by adding express and freight charges to the original bills. In this way students secure their books, and other supplies handled, at their actual cost to the College. The saving to the students, by the plan in vogue, is not less than 30 per cent. Another benefit derived from the plan is having the books—and the desired edition of the same—when they are needed.

Two summaries of text-book inventories have been prepared since the last report. They are as follows:—

JUNE 1, 1896.

	Sold.	Inventoried.
Text-books	$ 353.65	$ 784.10
Drawing supplies	275.42	209.60
Stationery	54.45	14.10
Total	$ 683.52	$ 1,007.80

NOVEMBER 15, 1896.

	Sold.	Inventoried.
Text-books	$ 794.95	$ 1,630.95
Drawing supplies	86.85	444.95
Stationery	79.07	181.40
Total	$ 960.87	$ 2,257.30

I have paid to the Secretary of the Board the sum of $1,644.39 and hold his receipts therefor.

ENROLLMENT OF STUDENTS.

Since the last report, there has been a gratifying increase in the number of students enrolled. This is but one of the many testimonies of the rapid growth of the College. It is doing a work that is grad-

ually but surely becoming better understood and more highly valued by our people. The result of such knowledge is the increased attendance of students and the larger number of counties represented therein.

The college-year of thirty-nine weeks is divided into three terms of equal length. The Fall term, that opens on the first Monday of September, closes at the time when the annual report is written. The enrollment statistics for this term—covering a period of five years—are herewith given:—

Year.	Males.	Females.	Total.
1892	127	36	163
1893	93	37	130
1894	148	57	205
1895	144	62	206
1896	202	88	290

The 290 students, registered in the Fall term of 1896, represent eleven states and one territory, as follows:—

Colorado, 270; Wyoming, 5; Kansas, 2; Missouri, 2; Wisconsin, 2; California, 2; Iowa, 1; South Dakota, 1; Illinois, 1; Ohio, 1; North Carolina, 1; New Mexico, 2; Total, 290.

The students from Colorado represent twenty-seven counties as herewith shown:—

Arapahoe, 10; Boulder, 13; Chaffee, 11; Clear Creek, 2; Conejos, 2; Delta, 8; Douglas, 1; Dolores, 1; Eagle, 5; Elbert, 2; El Paso, 1; Fremont, 8; Garfield, 2; Grand, 2; Gunnison, 3; Huerfano, 3; Larimer, 168; Las Animas, 2; Logan, 1; Mesa, 1; Montrose, 1; Otero, 3; Ouray, 1; Park, 2; Routt, 2; Saguache, 1; Weld, 14; Total, 270.

The total enrollment for the term named is divided among the different college classes as follows:—

Preparatory class	17
Sub-Freshman class	41
Students classified as irregulars	26
Students in Commercial College	80
Freshman class	55
Sophomore class	31
Junior class	25
Senior class	15
Total	290

The college-year closes with the exercises of "Commencement Day" in June. The enrollment of students and the number of graduates for each year since the opening of the College are shown in the table that follows:—

Year.	Males.	Females.	Total.	Graduates.
1880	14	11	25	0
1881	35	22	57	0
1882	49	32	81	0
1883	50	31	81	0
1884	40	37	77	3
1885	50	46	96	6
1886	45	42	87	1
1887	63	42	105	4
1888	71	38	109	4
1889	73	34	107	2
1890	56	18	74	9
1891	77	29	106	3
1892	101	45	146	7
1893	135	44	179	7
1894	142	56	198	7
1895	164	66	230	13
1896	161	71	232	12
1896*	202	88	290	0

A large attendance of students is but one evidence of College growth. There is danger that the desire to secure students may be too eager, leading to the admission to college classes of persons insufficiently prepared for the work. Quantity counts for much; *quality* should count for more. The influx of a large number of inadequately prepared students into the College sends threads of demoralization through the whole fabric.

Our desire is to secure students who are prepared for our work and are willing to do it. Experience shows that *willingness* to do work is at least equal in importance to the *ability* to do it. Every year brings us some students who fail to make class standing because they can not be induced to make use of the natural powers of

* Fall term ending November 30, 1896.

mind they possess. Laziness, shiftlessness, and indifference are not common words in our college vocabulary. The student's disinclination to work, where it exists, is not the outgrowth of college environment; but is a product he imports from former associations at home.

The work of every college department is planned to give those who undertake it but little time for anything else. The person who comes to the College in expectation of "*joining*" every organization that student ingenuity can devise will soon, after arrival, find himself relegated to the tail of his classes. The student who is "Jack-of-all-plays" is rarely master of any of his lessons.

I have no space in which to discuss the relative merits of *large* and *small* colleges, as the terms are usually understood. The subject is broad enough to admit of something being said on both sides. The advocates of the small college are usually found to be connected with one. My own opinion is that there is a healthy limit to the enrollment record of an educational institution—that limit being pushed up or down according to circumstances.

Under what I might call *normal* conditions, a college enrollment of over five hundred students would not be desirable. I have seen high-grade scholastic work done in an institution that could not assemble two hundred students at general exercises. Take an institution with *one* well-planned, fairly-comprehensive course of study—give it two hundred students classified substantially as follows: Freshmen, 80; Sophomores, 60; Juniors, 40; Seniors, 20—provide a capable teaching force large enough to secure the necessary sub-division of classes; and some conditions are present highly favorable to educational growth of the best kind.

Ideal conditions can not often be secured. Our arrangement of college work and classification of students, while not beyond just criticism, perhaps, are productive of good results. The educational work could be improved by a closer classification, one that would compel some to take the work of a lower class and exclude others from *college* work altogether until ampler preparation be made.

COURSES OF STUDY.

The College offers students a choice from five distinct courses of study, namely—Agricultural; Mechanical Engineering; Civil and Irrigation Engineering; Ladies'; and Commercial. These courses, with the exception of the one last named, require four years' uninterrupted work for their successful completion. Students who complete either of these courses to the satisfaction of the college authorities receive the degree of Bachelor of Science. Post-graduate work is required for the degrees of Civil Engineer and Mechanical Engineer. The course of study in the Commercial Department covers a period of two years. This course provides for systematic work in all branches usually taught in the best business colleges of the country; and, in addition thereto, makes provision for much instruction in branches which properly belong to a general educational course. It is not the aim of the Commercial Course to attempt to fit students for bookkeepers and stenographers in the shortest possible time. Experience has clearly shown that persons of limited education, who take business courses, invariable fall into the lowest class of workers. The student who completes the two years' course is qualified to discharge the duties of a bookkeeper, private secretary, and shorthand amanuensis. Tuition in the classes of the Commercial Course, as in all other departments and classes of the College, is free. The needed text-books and materials are supplied to students at actual cost which, owing to the manner of purchase, is below the usual wholesale rate.

The Department of Domestic Economy began with the Fall term of 1895. The work of the new Department adjusts itself naturally and easily to the conditions under which all college work is prosecuted. There is no conflict of classes. Nearly all the lady students have taken up the work of the Department. There is promise that this work will be an interesting, a profitable, and a popular part of the instruction of the students who take the "Ladies' Course" in the College.

The course of the Preparatory Department has been rearranged so as to make provision for two years' work. The work of the added class—the Sub-Freshman—includes some formerly required of the Freshman class. The present Preparatory class has the work usually included in the course for eight-year pupils in the common schools. Owing to the small attendance, and the excellent facilities for instruction, the members of this class have special advantages for prosecuting their studies. Then, too, they have access to the library, attend general exercises daily, and profit by the general management under which students are taught to respect, and yield obedience to, reasonable, lawful authority.

In the term just closed, classes in German, Latin, and Greek were organized. This action was taken in response to a call that it was thought best to heed. I am much pleased with the work that has been done. The number of students studying these languages is as large as was expected. Their instruction makes no interference with the regular scheduled work and entails but little expense upon the College.

The stress of future effort in the educational work of the College should be in the direction of making that work as now planned and in operation more efficient. There is no pressing need of new departments of instruction. The field now occupied is broad enough; the want of more thorough cultivation is the one most clearly in sight.

The books of the library are an educating force acting beneficially upon such students as are not afraid to handle them. If there was need of any large additions to their number, space is not to be had for their proper keeping. This condition of affairs suggests that the library appropriation for the coming year be made about sufficient to meet the cost of periodicals taken and book binding needed.

The teaching force in the Commercial Department must be increased. Possibly the present arrangement can be continued until the close of the college-year. The presence of eighty students in that Department calls for more room and additional teaching service.

It is my hope to see more effective teaching in all branches that give general culture. *Specialization* should follow, not precede, the acquisition of that knowledge that is said to be *common* but which is sometimes so *uncommon*. The illegible manuscript, the bad spelling, and the incorrect language of the student can not be condoned because he is able to show some familiarity with the terms used in science or mechanics. The most *practical* education that can be gained is that which enables its possessor to acquire the printed and spoken thoughts of others and to give expression to his own in correct English.

THE MOST EVIDENT NEEDS.

A profitable use could be made of a largely increased revenue. Many thousands of dollars could be spent in the erection of new buildings, supplying the scientific departments with much-needed apparatus, adding to the treasures of the library and museum, and making experimental work more far-reaching in its results. State pride and a wise financial policy might well unite to sanction the appropriation of liberal sums for the better endowment and support of all our State institutions were the money requisite within legislative reach. Possibly those in control of these institutions realize as keenly as the lawmakers themselves the futility of making any large demands upon the public treasury at this time. Some of the needs most pressing are stated:—

1. Completion of the new Chemical Laboratory.
2. Better quarters for the Commercial Department.
3. A new Library Building.
4. A Central Heating Plant.
5. An Electric Light Plant.
6. A Dairy-House with all necessary appliances.
7. A new building for the Department of Zoölogy and Entomology, with proper quarters for the College Museum.
8. Rooms for the College Literary Societies.
9. An Assembly Room suitable for Chapel and General Exercises.
10. An Armory, a Drill-Room, and a Gymnasium combined.

However desirable, and even necessary, all these improvements are, it is well understood that most of them can not be secured now; perhaps, not in the immediate future. An appropriation of $30,000 by the General Assembly, at its next biennial session, will suffice to meet the needs recognized, by those in control of the College, as most urgent.

The support of The State Agricultural College has not entailed a heavy tax burden upon the people of Colorado. Since the organization of the College, more than eighteen years ago, the State has made special appropriations in its behalf of just $49,500.00. These appropriations have been used solely for improving the real property belonging to the State of Colorado. At the time of the writing of this report, the State owns grounds and buildings, in the vicinity of Fort Collins, conservatively valued at $150,000.00. The departmental equipments with the library books are not worth less than $60,000.00. The experiment station property foots up a total valuation of over $25,000.00. The State, then, has something to show for the regular and special appropriations it has made for the College.

The best results of the expenditure of State money for college support is seen in the better equipment for life given hundreds of young men and women.

CONCLUSION.

There is no general consensus of opinion, even on the part of those engaged in it, as to what the work of an agricultural college should be. Undoubtedly, the present workings of the College are a decided evolution—shall I say revolution?—from those that met with the approval of the first governing boards. The thought uppermost in the minds of the first Board members, as I interpret it from their official reports, was the founding of a school where theoretical and practical *agriculture* should be taught. The idea of promoting "the liberal and practical education of the industrial *classes* in the several pursuits and professions of life" was not made prominent by the course of study they authorized. Yet they builded

wisely; with limited resources they restricted their efforts to that line of work which congressional legislation had given most prominence. They could not with certainty look far into the future. No true image of the present could be seen in the unpretentious beginning of eighteen years ago. One small building, three instructors, twenty students, and a few hundred dollars of revenue did not give any sure promise of the present status of the College.

There is plenty of evidence to attest the fact that, with all the changes made in our scheme of instruction, the agricultural phase of education has kept the upper place. The most costly and beautiful buildings on the college grounds to-day are those devoted to the great interests of agriculture and horticulture. The new building, now in course of construction, will be the handsomest one on the campus. There is no thought of using any part thereof, save for instruction and experimental work in those sciences with which agriculture has so much to do, i. e., chemistry and geology.

Irrigation is so closely related to agriculture in Colorado that its intelligent study may well engage the attention of those who design making the cultivation of the soil a means of gaining a livelihood. Our Irrigation Engineering Building, with its elaborate and costly equipment, does not testify to any purpose of weakening instruction of most service to the farmer. Yearly, the most liberal appropriations of money made by the Board go to those departments of the College whose work touches most closely and vitally that first and most important occupation of men—*Agriculture.*

Respectfully submitted,

ALSTON ELLIS,
PRESIDENT.

Fort Collins, Colorado,
December 9, 1896.

ADDENDUM.

Everything connected with the early history of the College is, even now, possessed of more than passing interest. That interest will increase with time and the

more rapid growth of the College. I am fortunate in securing a newspaper copy of the Board's First Annual Report. Its publication will serve to make the report record of the College more complete and for that reason, and the additional one that the report itself presents matters of moment, I recommend its publication.

The brief letters of the first President and the first Secretary of The State Board of Agriculture are freighted with interest and may well find a place in this year's report. They were written at my solicitation. All these form an important contribution to college history.

REPORT

OF THE

STATE BOARD OF AGRICULTURE.

(October 27, 1877.)

HON. JOHN L. ROUTT,

Governor of the State of Colorado:

Sir: In compliance with Section 10 of the law creating the "State Board of Agriculture," I have the honor to submit the following report:—

At the first meeting of the State Board of Agriculture the title to the college lands was not vested in the State. I am now able to report that the title to two hundred and forty (240) acres of land is vested in the State Board of Agriculture, and their successors, in fee simple.

Owing to the fact that the Agricultural College of Colorado is an institution to be erected and operated in the future, I am unable at this time to make a report covering the wide range which the law contemplates when the College shall be in full operation.

At the first meeting of the Board, the President and Secretary were appointed a committee to receive and care for the personal property belonging to the College. That duty has been performed, and a report thereof presented to the Board. With the consent of the Board, President Watrous was made temporary treasurer of the fund received from the "Board of Trustees" of the Agricultural College, and at the Meeting of September 11, 1877, he submitted the following report of the fund in his hands, to-wit:—

RECEIPTS.

March 26th, 1877—Received of B. T. Whedbee, former Treasurer of the Agricultural College, one note of hand for.................................$	417.24	
April 5th, 1877—Received of W. C. Stover one year's interest on the above note.........................	75.10	
July 6th, 1877—Received of Charles Ramer for hay cut on college land................................	6.00	
Total		$ 498.34

DISBURSEMENTS.

March 19th, 1877—Paid W. F. Watrous's bill for expenses to Denver to attend the first meeting of the Board...$	12.00	
April 30th, 1877—Paid H. Stratton's bill for expenses to Denver to perfect title to college land........	20.00	
May 26th, 1877—Paid to H. Stratton for stationery for Secretary's office................................	5.00	
May 26th, 1877—Paid for telegram....................	2.00	
April 23d, 1877—Paid W. F. Watrous's bill for furnishing and setting 152 cottonwood trees, at 20 cents each..	30.40	
June 1st, 1877—Paid J. M. Galloway for abstract to college lands....................................	12.00	
June 1st, 1877—Paid for postage and acknowledging deed	.75	
July 20th, 1877—Paid W. F. Watrous's bill of expenses to Greeley to obtain signature to deed..	6.00	
Total		$ 88.15
Balance on hand................................		410.19

GENERAL NOTES.

The past season has been one of unusual prosperity; and the farmer has been blessed with bountiful crops. The weather during the last part of February and the entire month of March was very mild and pleasant, which, combined with the fact that a large portion of the wheat ground was plowed last fall, enabled the farmers to put

CIVIL ENGINEERING BUILDING.

in their wheat a month earlier than usual. During the months of April and May the temperature was quite cool, with sufficient rainfall to push the small grain crop forward with a vigorous growth, while the corn was very much retarded and hardly commenced growing until the warm weather of July and August; but the continual good weather of the fall gave ample time for the crop to mature.

The wheat crop, as far as I have been able to learn, has surpassed any crop ever grown in Colorado. The average yield is very large and the wheat is of superior quality. Quite a large number of farmers in Larimer county have threshed 40 to 50 bushels to the acre as an average for their entire crop. The wheat crop has been remarkably free from rust; while the smut has affected some fields badly.

There seems to be a difference of opinion among the most intelligent farmers as to the virtue of blue-stone in preventing smut in wheat. The weight of evidence, however, is quite strong in favor of soaking the seed, before sowing, in a solution of blue-stone, which destroys the fungoid growth and prevents the propagation of its species.

The past season's experience of early sowing of wheat, combined with that of former years, must necessarily teach the enterprising farmer that the royal road to success is through *fall* plowing and *early* sowing. The practice of harrowing winter wheat in the spring of the year has obtained to some extent in the western states; and reasoning from analogy, Mr. P. M. Hinman, of Boulder county—a member of the Board—having a field of wheat which failed to have a good stand, and whose general outlook was every way inferior to the balance of his wheat, decided to harrow the field and note the results. The harrow was faithfully applied when the young wheat was four to six inches high. Many of Mr. Hinman's neighbors, who witnessed the operation, were very free to express their opinion that the wheat would be ruined. Such, however, was not the case, as Mr. Hinman informed me that immediately after the harrowing

the wheat took on a better look, and commenced growing rapidly; and at harvest time the field so treated gave the largest yield. The result was so marked that Mr. Hinman intends to adopt the plan in the future in the cultivation of his wheat crop.

Another very important matter as regards the wheat crop, is the manner of seeding; that is, whether sown broadcast or drilled in. Our best farmers in Larimer county, and generally in the State, adopt the drill, for three very good reasons: 1st, it saves one-quarter the seed; 2d, it produces a greater yield; and 3d, it is less labor. In my own case, I sowed twenty acres broadcast, which gave a yield of twenty-seven bushels per acre; and seven acres put in with a drill averaged thirty-eight bushels to the acre—a difference of eleven bushels in favor of drilling. Wheat drilled in after corn or potatoes, without plowing, has always produced the best results in this county.

THE LOCUST.

The locust or grasshopper hatched out in the early spring, but seemed to lack vitality, and did little or no damage to the growing crops. As far as my own observation extended, I was unable fully to satisfy myself as to the causes that operated so effectually to destroy the young grasshopper. I observed what I supposed to be the full-grown 'hoppers flying very high, but by using a field glass I discovered them to be the ichneumon fly. It is undoubtedly true that this fly is very destructive to the locust, and if it continues to multiply will eventually destroy the locust entirely.

IRRIGATION.

The question of the water supply and its control by legislation is one of vast importance, and should be treated very carefully by our future legislators, until such time as the experience of the farmers in different localities shall enable them to decide upon the best method of contracting it. My own opinion is, that such source of supply, and the valleys tributary, should form

a district by itself, and come under the action of local laws made by the actual consumers of the water in each district.

AGRICULTURE.

Agriculture being the foundation upon which the business structure of the state is built—all business being buoyant and depressed in proportion to the prosperity or failure of the agriculturist—it seems to me that the coming man, politically, will be he who by wise and liberal policy shall protect and advance the farming interests of the State, not forgetting the corner-stone—The Agricultural College.

HARRIS STRATTON,

Secretary State Board of Agriculture.

EXTRACTS

FROM

PRESIDENT WATROUS'S REPORT.

(OCTOBER 27, 1877.)

"Upon the State Board of Agriculture devolves the important duty of organizing and pushing forward this enterprise, (i. e., establishing a school where practical farming may be taught.) We are the custodians of an interest that is vastly more important to the people of Colorado than the one-tenth of a mill tax which has been appropriated for the benefit of the Agricultural College, namely, making this agricultural school of the Centennial State a success."

"Under the law that created the State Board of Agriculture, the agricultural farm is to be devoted to experimenting on different kinds of grain, grasses, fruits and timber, manner of cultivating and irrigating, of planting and harvesting; thereby giving the agriculturist much practical knowledge at a very little cost."

"I wish to call your attention to the fact that the law has been complied with in its relation to the agricultural lands, and the Secretary of State has ordered a levy of one-tenth of a mill tax, which will create a fund of $4,500. This tax will be paid into the State Treasury next winter subject to the control of the Board."

"I would recommend that the Board, at the present session, take steps preparatory to erecting a suitable

school building. One that will meet our present wants can be built and left convenient to add to when it becomes necessary."

"As men interested in the agricultural interests of Colorado, let us be in earnest in this matter. The great world must be fed, and with all the energy and ability that God has given us, let us push this enterprise forward and make the Agricultural College of this our Centennial State a success."

REPORT

OF

COMMITTEE ON COLLEGE LANDS.

(SEPTEMBER 11, 1877.)

W. F. WATROUS,

President of the State Board of Agriculture:

Sir—In accordance with the instructions of the Board at its first meeting, I have the honor to report that I have received the signatures of nine of the Trustees of the Agricultural College to a deed of transfer, and have filed said deed in the County Clerk's office for record. Also that quit claim deeds have been signed by all parties claiming any interest of whatever nature in, or to, the land belonging to the Agricultural College; and that the State Board of Agriculture now has a complete and perfect title to the 240 acres of land formerly held by the Trustees of the State Agricultural College. And, further, that the Hon. A. J. Sampson, Attorney-General of the State, has been notified of the fact in accordance with the requirements of the law creating the Board. All of which is respectfully submitted by your Committee,

HARRIS STRATTON.

LETTER FROM W. F. WATROUS.

(FIRST PRESIDENT OF THE STATE BOARD OF AGRICULTURE.)

DR. ALSTON ELLIS,

President of The State Agricultural College:

Sir—When, during Colorado's Constitutional Convention, an article was agreed upon, locating the State Agricultural College at Fort Collins, representatives from other localities did not consider their loss irreparable or Fort Collins's emolument beyond compare. The affair was looked upon as something in the nature of a burlesque. A school for the promotion of agricultural science and mechanic arts, located in the Great American Desert, with nothing in sight more suggestive of enlightened civilization than dry prairies, dotted with cactus patches, bestrewn with bleaching bones of the departed buffalo, and inhabited by prairie dogs, coyotes, and buzzards, with only here and there, in little oases along the creek bottoms, a few adventurous specimens of the *genus homo*, was an enterprise which was considered both amusing and pathetic. It was passed upon without very serious consideration at the time, though afterward, when its importance was better appreciated, a determined effort was kept up for several years to secure its removal from Fort Collins to some other locality. It required several years of alert watchfulness and defensive resistance to prevent this being accomplished.

The first money secured, to be applied in the interest of the future College, was raised through the patronage of an old-fashioned Christmas tree. A project had been formed by the good people in and adjacent to Fort Col-

lins, which had for its object the creation of a public library. The result of the evening's entertainment, was a sum of money approximating $80.00. This sum was appropriated, treasured, or, perhaps, held in "escrow," or at any rate, held, by certain individuals for a period of years and finally entered a sphere of usefulness in the following manner:—

The first legislative appropriation was for one thousand dollars, made contingent upon the donation by the citizens of Fort Collins of a similar sum. The individuals holding the library fund were industriously wrought upon and finally did render assistance in the sum of forty dollars which sum was duly applied to the benefaction of prospective college interests. A town improvement company, in existence at the time, consented to the sale of several lots and, with many large and small donations, the requisite amount was raised and the appropriation secured. With this money a five-board fence was constructed around the forty-acre tract, now largely occupied by the college and department buildings, and a one room brick house, about 14×28 feet, as to dimensions, was built just east of the present Domestic Economy Building. This house was sometimes occupied by campers and sometimes by renters; afterward it was used as a tool-house and, still later, as a chemical laboratory. Its unpretentious walls were at one time consecrated to learning, and made repositories of sacred memories, through sheltering for a considerable period the first President of the College and his family.

When operations were set on foot to secure the location of the 90,000 acres of land for the benefit of the College, according to the provisions of the "Morrill Bill," it was found that the bill had fallen short of its probable design, in that it applied only to states actually in existence at the time of its passage. The matter could not be approached until an enabling act was passed by Congress, which legislation was accomplished largely through the efforts of Senator H. M. Teller; whereupon a Land Board was appointed, who proceeded to locate the land as prescribed.

AGRICULTURAL BUILDING.

After the forty-acre tract was fenced, the tillable land was farmed for several years by different parties, the Grange, as an organization, cultivating a crop one year. A number of the farmers turned out with teams and implements in the spring, plowing and sowing the land, all in one day, the women folks preparing a wholesome, old-fashioned dinner, after the manner of log-rollings and husking-bees. The cottonwood grove on the north side of the grounds, which is steadily disappearing, began its existence that spring in the form of cuttings placed in the gound by these enterprising Grangers and their hopeful boys and girls.

After the admission of Colorado to the Union, a new Board was appointed and an appropriation of one-tenth of a mill tax secured. This furnished an income of $4,000 per annum, the first year's increment being allowed to remain in the State Treasury until the second installment became due, when a contract was let for the erection of the first Main Building for the sum of $7,000. The contractor failed before the building was completed and no less than six mechanic's liens were filed on the property by interested parties who took this short and easy method to learn that mechanic's liens don't "stick" on state property. However, the matter was compromised, creditors receiving sixty per cent. of claims, and the building was made ready for occupancy.

At the session of the legislature in the winter of 1878-'9, a bill was introduced calling for a special appropriation of $3,000, with which to open the College in the following September. The bill passed the House but was killed in the Senate. Two members of the State Board of Agriculture were appointed a committee to go to Denver and advocate whatever measure seemed best or most promising toward the mitigation of the exigency at hand.

The Legislature had, during this session, passed the bill raising the regular college appropriation from one-tenth to one-fifth of a mill and the Senator from our district had inadvertently promised that, if this bill were passed, he would ask for nothing more for the College at that session.

The last day of the term had arrived and all hope of original legislation was gone. One member of the committee went to the State Treasurer and suggested the plan of borrowing $2,000 from the State, giving a certificate of indebtedness, making the sum payable, when the next year's appropriation came due. The Treasurer saw no objection to this plan, but said it could not be done as the time had expired for the introduction of bills. This fact proved not to be a fatal impediment, for the old "dead head" special appropriation bill was quickly resurrected, given a new rider, providing for the loan, and, by dint of much urging, was rushed through both houses and became a law, the Legislature adjourning very soon after.

It afterwards became necessary to borrow money in this manner several times and, on one or two occasions, when taxes came in slowly the money was not on hand when due and it became necessary to borrow from outside parties in order to pay the first debt. In these dilemmas, the Board was often ably assisted by the Hon. T. M. Patterson and other prominent men of Denver.

It is, perhaps, worthy of mention that during the first two, and most trying and arduous, years in the history of the College, the Board members rendered their services gratis and the Secretary received a salary of $100 per annum.

Very truly yours,

W. F. WATROUS.

Fort Collins, Colorado,
November 23, 1896.

LETTER FROM HARRIS STRATTON.

(FIRST SECRETARY OF THE STATE BOARD OF AGRICULTURE.)

Fort Collins, Colo., Nov. 18, 1896.

DR. ALSTON ELLIS,

President of The State Agricultural College:

Dear Sir—At your request I herewith submit to you a few personal recollections of the early history of the College and the State Board of Agriculture.

At the November election in the year 1867, I was elected to represent the county of Larimer and Weld in the Territorial Legislature. During the session, I gave the matter of locating a State Agricultural College, at Fort Collins, careful attention, intending to introduce a bill in the House for that purpose.

After careful examination of the law of Congress, passed in 1862, granting public lands to the different states for agricultural college purposes, I came to the conclusion that as the time specified in the law for the states to accept the offer of Congress had expired and, further, that the law did not apply to the territories, I reluctantly gave up the idea. In 1870, Mr. Taylor succeeded in having passed "An Act for the Establishment and location of an Agricultural College" to be located at or near Fort Collins. In 1874, Hon N. H. Meldrum secured the passage of "An Act Concerning the Agricultural College of Colorado," in which one thousand dollars was appropriated, on condition that the citizens of

Larimer county shall subscribe one thousand dollars and shall have expended the same on buildings and the ground.

The Grange raised a portion of that sum, the balance being subscribed by the town company and the citizens of Fort Collins. A small one-story brick building was built on the northeast corner of the college grounds, which probably cost about five hundred dollars. What disposition was made of the balance of the money I do not know.

When the first Legislature convened in Denver in 1876, I was elected Sergeant-at-Arms of the Senate. Colorado having been admitted into the Union, I felt satisfied that by proper legislation the 90,000 acres of land could be secured. I examined the various state laws in reference to agricultural colleges, and finally decided that the Michigan law was the best adapted to our wants in Colorado. I therefore remodeled the Michigan law so as to meet the wants of our State, and placed the draft in the hands of N. H. Meldrum, a member of the Senate from Larimer county, who introduced the bill, which was finally passed creating the State Board of Agriculture. It was my aim and desire, in drafting the bill, to give the sons and daughters of the farmers of Colorado an opportunity to attend a college in which they would be taught scientific farming, the mechanic arts, and domestic economy.

In making the appointment of the first Board, Governor Routt complimented me by saying that I had evidently done more than anyone else in securing the passage of the law, and he wished me to accept a position on the Board. Governor Routt further said, that he would appoint John Armor and P. M. Hinman, and for the other five members he would appoint any good men I might name. I submitted the names of W. F. Watrous, John J. Ryan, W. A. Bean, B. S. LaGrange, and M. N. Everett, and Governor Routt appointed them as members of the Board.

The first meeting of the State Board of Agriculture was held in the Governor's office, in Denver, March 19th,

1877. W. F. Watrous was elected President and Harris Stratton, Secretary.

The Board had many difficulties to contend with in the erection of the college building and getting the institution started in a small way. During the four years that I was a member of the Board, I realized that some advancement had been made; but in my most sanguine expectations I did not anticipate that in fifteen years I would see a faculty of fifteen members and three hundred students in attendance at the College.

Believing that my first report as Secretary of the Board, which was never published, should appear as a matter of record, I herewith submit the same as preserved in my scrap-book.

Yours truly,

HARRIS STRATTON.

NINTH ANNUAL REPORT

OF

THE AGRICULTURAL EXPERIMENT STATION

OF

COLORADO

FOR THE YEAR 1896

HOME STATION
Fort Collins, Colorado, December 9, 1896

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

BOARD OF CONTROL:

THE STATE BOARD OF AGRICULTURE.

Executive Committee in Charge:

Hon. A. L. Kellogg, *Chairman*, Hon. J. E. DuBois,
Hon. J. J. Ryan, Hon. A. S. Benson,
President Alston Ellis.

STATION COUNCIL.

Alston Ellis, A. M., Ph. D., LL. D........President and Director
W. W. Cooke, B. S., A. M........................Agriculturist
C. S. Crandall, M. S.................Horticulturist and Botanist
W. P. Headden, A. M., Ph. D..........................Chemist
L. G. Carpenter, M. S......Meteorologist and Irrigation Engineer
C. P. Gillette, M. S..............................Entomologist
D. W. Working, B. S...............................Secretary
L. M. Taylor, B. S., Stenographer.

ASSISTANTS.

F. L. Watrous...................................Agriculturist
J. H. Cowen, B. S..............................Horticulturist
C. J. Ryan...Chemist
R. E. Trimble, B. S.......Meteorologist and Irrigation Engineer
Emma A. Gillette...............................Entomologist

SUB-STATIONS.

P. K. Blinn, B. S..............................Superintendent
Arkansas Valley Experiment Station, Rocky Ford, Colorado.
C. A. Duncan, B. S............................Superintendent
San Luis Valley Experiment Station, Monte Vista, Colorado.
J. E. Payne, M. S..............................Superintendent
Rainbelt Experiment Station, Cheyenne Wells, Colorado.

THE STATE AGRICULTURAL COLLEGE.

SECRETARY'S FINANCIAL STATEMENT OF THE EXPERIMENT STATION FUND FOR THE FISCAL YEAR ENDING JUNE 30, 1896.

Receipts.	United States.	College.	Total.
United States Treasurer	$ 15,000.00	$	$ 15,000.00
Farm Products	....	2,952.71	2,952.71
Overdraft	....	65.23	65.23
Total	$ 15,000.00	$ 3,017.94	$ 18,017.94
Expenditures.	United States.	College.	Total.
Salaries	$ 9,224.36	$ 1,468.28	$ 10,692.64
Labor	2,304.48	333.30	2,637.78
Publications	522.40	235.40	757.80
Stationery	113.08	....	113.08
Freight and express	70.68	18.11	88.79
Heat, light, and water	6.85	....	6.85
Chemical supplies	54.30	30.60	84.90
Seeds, plants, and sundry supplies	575.90	27.70	603.60
Fertilizers	96.00	75.00	171.00
Feeding stuffs	326.38	123.00	449.38
Library	19.04	....	19.04
Tools and implements	222.31	132.00	354.31
Furniture and fixtures	36.29	....	36.29
Scientific apparatus	123.48	....	123.48
Live stock	1,029.50	....	1,029.50
Traveling expenses	179.66	120.15	299.81
Contingent expenses	10.00	454.40	464.40
Buildings and repairs	85.29	....	85.29
Total	$ 15,000.00	$ 3,017.94	$ 18,017.94

Letter of Transmittal.

HON. ALBERT W. McINTIRE,

GOVERNOR OF COLORADO.

Sir—The Ninth Annual Report of the Agricultural Experiment Station, agreeably to Section 3 of an act of Congress approved March 2, 1887, is herewith submitted.

The station work, in its prosecution under schedule, has presented but few new phases since my last annual report. The Board of Control was reluctantly forced, by lack of finances available for the further support of all the sub-stations, to discontinue experimental work on the lands located in El Paso and Rio Grande counties. The possession of these lands is yet retained, and hope is strong that some way will be open for the resumption of active experimental work thereon at an early date.

It is known that this desirable end can not be reached save by legislative appropriation for sub-station support, as the authorities in control of the United States fund have prohibited the use of any portion thereof for experimental work other than that in operation at the Home Station.

Most persons conversant with the purposes of station work recognize the necessity of more of that work than can be done profitably at a single station. The conditions under which farm operations are carried on in Colorado differ greatly. The methods that are employed with satisfactory results in one locality may not be wholly applicable to another. There must be some way of noting these varying conditions and providing for successful effort under them.

The sub-station management, operative as it has been in four different sections of the State, has been serviceable in helping to apply general rules to particular conditions.

The continuance of experimental work at the sub-stations is in close line with the policy that seeks the betterment of one of the rapidly growing interests of the State. Our material interests are vitally connected with the prosperity of our farming communities.

Methods of agriculture must not be left in a primitive state. Each farmer must not be left to gain needed experience from his own unaided, and often abortive, efforts. The work of the experiment station should be planned to help him by showing clearly how his efforts can be made more far reaching and thus attended with greater profit.

The plan of co-operative work, now so successfully followed in many states of the Union, and in Canada, would be productive of good results if made a part of our station work. Through it, the number of persons making experiments, and records thereof, in agriculture and horticulture would be largely augmented. Useless duplication of effort would be avoided and each worker would be brought in close touch and sympathy with his fellows. The published results would be common property; of value to those instrumental in their accomplishment and suggestive and helpful to others as well.

These suggestions, and others found in the body of the report, are made in the hope that wise legislative action may provide better ways and means than are now within reach for making them effective.

Respectfully submitted,

ALSTON ELLIS,

Director of the Agricultural Experiment Station of Colorado.

Fort Collins, Colorado,
December 9, 1896.

REPORT OF THE DIRECTOR.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—The year, whose station work is to be reported herein, began under peculiar conditions. At the close of the last year, it was pretty well understood that a change in station management was imperative. It was known, too, that the radical change which seemed necessary to carry out the letter of the law would arouse the antagonism of two classes of people—those who did not rightly understand the plan of station operations contemplated by the law and those who had some selfish interests to further in the continuance of the established order of things.

The "Hatch Act" of March 2, 1887, provides for the support of an "Agricultural Experiment Station" in connection with the college, in each state and territory, established under the provisions of the act of Congress bearing date July 2, 1862, and best known as the *first* "Morrill Bill." Congress, by the terms of this "Hatch Act," is required to make a special appropriation, annually, of $15,000 to meet the expenses connected with the work of said station.

The provisions of the congressional act of 1887, were formally accepted by act of the General Assembly of Colorado approved March 25, 1889. Prior to the latter date, i. e. on April 4, 1887, the General Assembly had provided for the location of four sub-stations—one on the "Divide" in the northern part of El Paso county, one in the Arkansas Valley, one in the San Luis Valley, and

one in Delta county—and placed them under the control of The State Board of Agriculture. That body was authorized to spend such amount as was deemed necessary, in establishing these sub-stations, out of the United States appropriation before referred to.

The State has never appropriated a dollar to the support of any of these sub-stations. The act of the General Assembly, approved April 3, 1893, by which another sub-station, now known as the Rainbelt Station, was located at Cheyenne Wells, made an appropriation of $2,500 for buildings and other permanent improvements.

At the beginning of the present year, nearly 800 acres of land, all reputed to be experimentally cultivated, were under the control of the Executive Committee, acting in the name, and by the authority, of The State Board of Agriculture. The money to carry on the extensive experimental work, or rather farm work, was taken from the United States fund and the receipts from sales of farm products.

The thought, expressed by some, was that these sub-station farms should be made self-sustaining; that is, that the crops raised should, when sold, meet a very large part of, if not all, the cost of labor and equipment. Managed as farms, the sub-stations presented no appearance, and gave no results, that entitled them to more favorable notice than adjoining lands tilled by enterprising farmers. In some instances the handling of these sub-station farms was the subject of unfavorable comment on all sides.

My first report, as Director, made earnest recommendation that all experimental work at the sub-stations be brought within narrower limits, and that farm operations, with an eye single to *profit*, be wholly abandoned. I felt, as others did, that the sub-stations as farms were not meeting the just demands of the people or fulfilling the requirements of the law.

In the summer of 1895, Dr. A. C. True, Director of the Experiment Stations, Washington, D. C., visited the College and made a careful investigation of the experiment station work then in progress and the manner in

which the United States fund for the promotion of that work was being expended. The result of this visit, and visits to a number of stations in other states, was the issuing of Circular No. 29, from the Office of Experiment Stations, under authority of the United States Department of Agriculture. The "Circular" is dated March 10, 1896. I am strongly tempted to give it in full, in this connection, because it is a clear and authoritative statement of what is required, in each state, in the way of experimental work under the provisions of the "Hatch Act."

A few quotations from the language of the "Circular" may serve a useful purpose:

"This Department holds that the expenditure of funds appropriated in accordance with the provisions of the act of Congress of March 2, 1887, for the maintenance of permanent substations, is contrary to the spirit and intent of said act. The act provides for an experiment station in each State and Territory, which, except in cases specified in the act, is to be a department of the college established under the act of Congress of July 2, 1862. The objects of the stations as defined in the first mentioned act are evidently of such a character as to necessitate the services of scientific and expert workers. Most of the lines of investigation named in the act are general rather than local, and involve scientific equipment and work. The sum of $15,000 which is annually appropriated by Congress under this act for each station is only sufficient to carry out a limited number of investigations of the kinds contemplated by the act.

"Thorough work in a few lines has been found much more effective and productive of more useful results than small investigations in numerous lines. When we consider the nature of the investigations, the amount of money provided for the work of each station, and the fact that the act expressly provides for only a single station in connection with each college, it becomes very clear that expenditures such as are necessary to effectively maintain permanent sub-stations ought not to be made from the funds granted by Congress to the States and Territories for experiment stations. The sums of money which can be expended for permanent improvements under the act of Congress aforesaid are so small that it is clear they were not intended to meet the needs of more than one station in each State and Territory.

"When the legislature of a State or Territory has given its assent to the provisions of the act of Congress of March 2, 1887, and has designated the institution which shall receive the bene-

fits of said act, it would seem to have exhausted its powers in the matter. The responsibility for the maintenance of an experiment station under said act devolves upon the governing board of the institution thus designated. If the legislature of the State or Territory sees fit to provide funds for the equipment and maintenance of other experiment stations and to put them under the control of the same governing board, well and good, but this does not in any way diminish the responsibility of the board to administer the funds granted by Congress in accordance with the provisions of said act.

"The performance of ordinary farm operations by an experiment station does not constitute experimental work. Operations of this character by an experiment station should be confined to such as are a necessary part of experimental inquiries. Carrying on a farm for profit or as a model farm, or to secure funds which may afterwards be devoted to the erection of buildings for experiment station purposes, to the further development of experimental investigations, or to any other purpose, however laudable and desirable, is not contemplated by the law as a part of the functions of an agricultural experiment station established under the act of Congress of March 2, 1887. Section 5 of that act plainly limits the expenditure of funds appropriated in accordance with said act to 'the necessary expenses of conducting investigations and experiments and printing and distributing the results.' "

Prior to the issuance of the "Circular," from which the foregoing extracts are taken, the question of curtailing, to some extent, the work undertaken at the substations came up for consideration in your Committee and a doubt as to the power, either of said Committee, or the Board represented by it, to cut off or materially to modify any portion of that work was expressed. An inquiry addressed to the State Attorney-General, Hon. B. L. Carr, brought a reply from which quotation is made: "There is nothing in the act of Congress which in my judgment contemplates the establishment of experiment stations other than those in connection with the several agricultural colleges and on and in connection with the agricultural college grounds. The purpose of the Act of Congress seems to be to have such stations under the charge and control of thoroughly-educated and scientific men, and to have them operated for scientific purposes and not merely for ordinary farming. It would

seem to be a diversion of the congressional fund if the same were to be applied to any other than purely scientific purposes."

Here we have two authorities, the highest outside of the courts of law to which we can go for legal advice, giving, independently of each other, substantially the same opinion. The officials at Washington have power to enforce their opinion by *act.* *

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* Under the head of "*Experiment Stations,*" the Hon. J. Sterling Morton, Secretary of Agriculture, in his annual report for 1896, says:

"Imperfect comprehension of the functions and duties of experiment stations on the part of governing boards and officers intrusted with the management of the stations has in many instances led to misdirected effort; in some to superficial work, and in others to expenditure of the public funds for work not contemplated in the original act."

"Some institutions have made the error of confusing work and expenditure intended for instruction with that intended for experimentation. Some stations expended large sums of money in what may have seemed experimenting, but was in reality the conduct and maintenance of large farms in which general crops (with, perhaps, some improved methods) were produced."

"The experiment station was not designed to be a model farm. There is neither warant in law nor justification in circumstances for making it such."

"Another seeming misuse of funds has been brought about by the acceptance of donations of farms from enterprising citizens or from communities upon condition that permanent substations should be established upon them. Such farms have often been accepted without properly considering the nature of the soil of the land donated or the real needs of the locality. Thus much money has been wasted for building and equipments upon farms where only superficial and temporary experiments can be conducted."

"Some stations have endeavored to cover too many lines of work. Many stations were organized originally as so-called 'all-around stations.' They had a large staff of officers called 'agriculturists,' 'chemists,' 'botanists,' 'entomologists,' and 'horticulturists.' They paid small salaries, and, with few facilities for work, achieved small results. Most of the officers were obtained from the agricultural college faculties. They were allowed very little time from their teaching duties therein, and consequently could not thoroughly conduct experimental investigations."

"The experiment station act gives the land-grant agricultural colleges $15,000 per annum especially for original research in agriculture. This is equivalent to 5 per cent. per annum upon an endowment of $300,000 for each station. And this fund ought to be regarded as a sacred trust and devoted entirely to the advancement of agricultural science through conscientiously directed original research. If this course be pursued in all the institutions, as it has been faithfully pursued in some, practical agriculture will receive vastly increased benefits."

If our station is to receive any financial aid from the Government, it must be operated in conformity with the interpretation of the law reached by the authorities at Washington. The agents of the Government act agreeably to its statutes and can not be expected to govern their official course by the legislative acts of any particular state. Our State by its voluntary acceptance of the terms of the "Hatch Act" has become a beneficiary thereunder and should in good faith do the part to which it stands pledged.

I have made quotation herein of the opinions of the Attorney-General of Colorado and the Director of the Experiment Stations, acting in behalf of the United States, to show clearly the reasons that prompted the Committee in control of the sub-stations in Colorado to abandon active experimental work at the Divide Station in El Paso county and the San Luis Valley Station in Rio Grande county, and largely to reduce the experimental acreage at the Arkansas Valley Station in Otero county and the Rainbelt Station in Cheyenne county. Necessity is the mother of many things beside *invention.* It is just as difficult to make something out of nothing now as it ever was.

There is an erroneous idea in the minds of most Colorado people, who have any care for or interest in the Experiment Station, as to the nature and amount of work it should undertake. It is generally known that the Government makes annual appropriation of $15,000 for the prosecution of experimental work in Colorado. Greedy eyes from every quarter of the State are fastened upon this appropriation and the desire to share in its distribution is without bounds. This idea of the right way of using the Government bounty has been fostered by the various Legislative acts establishing sub-stations and providing for their support by drafts upon the United States fund. This fund has proved wholly insufficient to secure satisfactory results in every part of the extended field in which experimental work has been attempted.

Consider the sum available for pushing station work, and then look upon it in progress in each of the five

scientific sections of the home station and upon four large experimental farms representing as many different sections of the State, and a conception of the thinness and worthlessness of some of it can be formed.

It can safely be said that but little of permanent value has resulted from the Colorado system of sub-stations. These sub-stations have had good supervision for what it has cost. It can not be expected that one who has fitted himself, by years of training, for planning and carrying into execution agricultural work on a *scientific* basis can be put in charge of one of these stations at a salary of from $50 to $70 per month. It is not strange that the management of our station work has provoked sharp criticism from those whose duty it is to guard against any misapplication of the Government fund.

Some sub-station or co-operative work seems called for by conditions existing in Colorado. This is readily admitted even by those who are in position to insist that no part of the Government appropriation shall be used in its furtherance. The feeling exists in the Department at Washington, that our State is not giving its Experiment Station proper support; that something more than the establishment of a number of sub-stations and putting them under the control of The State Board of Agriculture was implied in the Legislative act making acceptance, in the name of the State, of the congressional grant of 1887.

The people in the vicinity of the sub-stations, while differing in opinion as to the efficacy of their work, are almost a unit in desiring their continuance. Remonstrances against the abandonment of experimental work at the sub-stations at Monument and Monte Vista were prompt and vigorous.

At this writing, work at all the sub-stations is in a tentative condition. Its future will depend upon the financial help given it by the State. A small appropriation will enable The State Board of Agriculture not only to continue experimental operations at all the stations, but to render those operations more beneficial to the farming interests of the State than ever before. If those

who have been so earnest in remonstrance, in a direction where remonstrance was necessarily unaviling, will give active support to an effort that will be made to induce the State Legislature to make sure the permanency and value of sub-station work by needed financial support, their energy will be employed in a manner most promising of desirable result.

THE PRESENT STATUS OF THE SUB-STATIONS.

When it was decided a year ago temporarily to lease the sub-station lands in El Paso and Rio Grande counties, a Special Committee of the Board of Control was appointed with power to suggest, and approve of, the terms and conditions of leases to be drawn between the parties interested.

The Superintendent of the Divide Station, in El Paso county, having declined to remain as tenant, was requested to make sale of such products as were on hand, to the best advantage, and to ship the stock and all implements to the Home Station at Fort Collins. The carrying out of these instructions left the Divide Station without supervision or equipment. At a meeting of the Executive Committee, held March 31, 1896, the Director was authorized to rent the station property to a proper person on the best terms obtainable. Acting on this authorization, I put W. A. Diebold, of Table Rock, Colorado, in possession of the land and buildings as tenant. Mr. Diebold agreed to pay $40 for the use of the premises for one year from March 1, 1896. He also agreed to pay $7 for the hay that had been left on the grounds. At the present time, Mr. Diebold is in charge of the Divide Station. He reports the farm operations of the year as fairly successful. *

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* Mr. Diebold has made payment of all money due from him under the terms upon which he took charge of the station property.

Some statements from him, regarding the crops grown, are herewith given.

"The grain was almost a failure. Two acres of Chinese hulless barley, sown June 5, caught the late rains and did well. Five acres of oats planted as deep as possible with a drill, April 11,

For the year ending November 30, 1896, the money account of the Sub-station is as follows:—

Superintendent's salary....................	$ 199.98	
Labor	2.00	
Other expenses..............................	63.64	
Total		$ 265.62

There is a credit of $36.85 derived from sales ordered to be made.

Charles A. Duncan, Superintendent of the San Luis Valley Sub-station, in Rio Grande county, became tenant of the property under the term of a lease that provided that he, having use of the station equipment, should farm the land for his own profit and at his own expense. He was also to do some stipulated experimental work and make report thereon at the proper time.

On November 15, 1896, after making out the annual inventory and forwarding to my office a brief report on the experimental work of the year, Mr. Duncan left the station property in charge of R. S. Sides. Information

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yielded 8½ bushels per acre. On April 13, five acres were sown to oats broadcast. The amount of seed, per acre, in each case was 1½ bushels. The latter field did not stand the severe winds of the latter part of April and the first part of May. This field was resown, May 27, with hulless barley, the same being put in by harrowing so as not to damage the oats, then a light stand. The barley, owing to light covering, did not germinate until late; but the result was an excellent hay crop of oats and barley."

"The first field of barley yielded 16 2-3 bushels per acre. One acre of buckwheat—two varieties—yielded 14½ bushels. Four varieties of potatoes—Late Ohio, Rochester Rose, Maggie Murphy, and Prize Taker—were planted. Prize Taker produced nothing larger than a walnut. One 50-foot row of Maggie Murphy potatoes yielded 21 pounds. Late Ohio, planted May 20, 21, and 23, yielded 2,000 pounds per acre. Rochester Rose, hand planted May 17 and 18, six inches deep, yielded 4,000 pounds per acre. The summary of products is given herewith."

Potatoes, all varieties, large and small, 28,000 pounds.

Oats, 42½ bushels.

Barley, 33 1-3 bushels.

Buckwheat, 14½ bushels.

"Bromus inermis did not grow more than six inches, on account, perhaps, of the sowing being too heavy to stand the drouth. In 1895, I sowed 1½ acres on my ranch, using about seven pounds of seed per acre. The yield therefrom, this year, was 172 pounds of nice, clear seed, worth 20 cents per pound."

received causes me to believe that the station buildings and land are not in the best condition. Mr. Sides may be just the proper person to take charge of our station property at Monte Vista, but there is no agreement of any kind whereby he can be held responsible for the proper care of the property. Some action looking to the care, or disposition, of the station property at that point is desirable.

The account with the Sub-station stands as follows:—

Superintendent's salary (prior to date of lease	$ 133.32	
Water rent	75.00	
Other expenses	5.88	
Total		$ 214.20

The receipts from sales of farm products are $86.50.

On February 28, 1896, your committee decided to continue operations at the Rainbelt Sub-station, in Cheyenne county, until November 30, 1896. J. E. Payne, M. S., was appointed Superintendent at a salary of $50 per month. Mr. Payne entered energetically upon the scheduled work. The report of his efforts will appear elsewhere. This Sub-station, Micawber-like, is "waiting for something to turn up." It ought to be kept in operation if money for its proper support can be secured. A three-year trial is not sufficient to demonstrate with any certainty the agricultural possibilities of the eastern portion of our State. The financial statement, covering a year, is as follows:—

Superintendent's salary	$ 600.00	
Labor	90.95	
Other expenses (improvements and equipment)	271.08	
Total		$ 962.03

A small credit from sales, amounting to $5.20, is noted.

On January 30, 1896, the following resolution was adopted by the Executive Committee:—

"*Resolved*, That A. L. Kellogg be authorized to lease all station land at Rocky Ford, not included in the special experimental area, for the current year on the best obtainable terms, the tenant to conduct his farm operations upon a plan to be agreed upon between him as one party and Mr. Kellogg and Superintendent Blinn as the other."

Under the authority given in this resolution, one hundred and twenty (120) acres of station land were leased to Francis Harson. By the terms of the lease the Station is to receive one-half of all hay and one-third of all grain grown on the leased land.

The remaining eighty (80) acres of station land contain the station buildings, the orchard, the experimental plots, and fields upon which general farm products are grown. The appearance of this portion of the Station property has been much improved. Intelligent observers mark the change for the better in the condition of the orchard.

The yearly expenditures for station support are herewith shown:—

Superintendent's salary	$ 759.96	
Labor	1,411.09	
Other expenses	781.51	
Total		$ 2,952.56

Farm sales up to the close of the year amount to $580.92.

The Arkansas Valley Station at Rocky Ford, Otero county, is the best sub-station under your control. The cessation of experimental work there would be a serious loss to the farming interests of the State. The land is eligibly located, being easily reached from the railroad station of the town. It affords the best possible conditions for the prosecution of that experimental work of most interest to the agricultural interests of the valley. Then, too, the people who come in touch with the station have ever shown the most lively interest in its welfare. There is little unjust criticism heard when people dis-

cuss the Station in conversation, or at public gatherings where the best methods of farming become the topics for consideration.

The Executive Committee, in control of station work, in planning the future of this Station, is brought face to face with a problem whose solution, at this time, is not readily apparent. The United States fund must, we are advised, be expended upon the station connected with the College, as a special department thereof. The same authority states in plain language that it is no part of the office of an experimental station to carry on farm operations as such.

With no available revenue for experimental work and with warning not to farm for profit, the open way for the continuance of sub-station operations is not clearly discernible. The carrying on of some "co-operative work," as has been suggested, is no way out of the difficulty; for the expense of this co-operative work can not be met by any draft upon the Government fund and there is no other within reach.

The land at Rocky Ford can not be handled, with any *experimental* value, so that expenditures and receipts will balance each other. A good farmer working for the preservation of the land and for what he could make it pay, would be able to meet all expenses, and more probably, out of sales of farm products; but no owner of the land, directing it through others, could bring about any such result. There would be no particular value to anyone in such result were it secured. The station, to meet any useful purpose, must keep the experimental side of its work uppermost. Some ordinary farm work is a necessity; but it is reasonable to require that no unnecessary effort be expended thereon.

The expenses of the Arkansas Valley Sub-station, under conditions now existing, will exceed the total receipts from sales at least $2,000 annually; and it is well understood, by those conversant with the nature of the work done, that no part of this excess can be saved but at the sacrifice of the efficiency and value of the experimental work.

The present sum paid for supervisory work is surely not excessive. If station work is to have any present or future value, it must be under the direction of one thoroughly-equipped, by reason of his scientific attainments and wide experience, for its prosecution. The one possessing such necessary qualifications, and having the will to make effective use of them, would well merit a salary of not less than $1,200 per year. Then, with a reasonable area upon which to carry on experimental work, the *labor* account ought to come within more modest limits. The labor bills, for the year, are about all that can invite criticism in the management of the Sub-station at Rocky Ford; and, possibly, they are not excessive when all the circumstances connected with the management are fully known.

As bearing upon the question of sub-station continuance, I quote the body of a letter from Dr. A. C. True, Director of Experiment Stations, Washington, D. C.:—

Dear Sir—"Referring to a report by Dr. Allen on his visit to your station last June, I wish to commend the management of the station on the action taken with reference to the sub-stations. I hope that there will be no relaxation of effort toward getting rid of this incubus and that the State legislature may be persuaded to deal generously with the station this winter. I fully believe that if you could have a relatively small amount of money for co-operative experiments in different parts of the State as circumstances may require, it would be far better than to maintain permanent sub-stations which at the best can be little more than stations for the trial of different kinds of crops."

THE WORK OF THE HOME STATION.

Ever since the life of the College began, important experimental work has been prosecuted on the college lands adjacent to Fort Collins. Prior to the receipt of the revenue obtained under the terms of the "Hatch Act," all expenses of the work referred to were met by orders on the tax-fund for college support and the receipts from farm sales.

The early reports of the Secretary of The State Board of Agriculture contain much matter which, under existing conditions, would find its way to the public by means of our station bulletins. The reports from the departments of Agriculture, Botany and Horticulture, and Chemistry, made before "The Agricultural Experiment Station" became a college department in February, 1888, present much interesting information upon questions of vital interest to "agriculture and kindred pursuits."

The present organization of the force engaged in station work at the College is simple and effective. The Executive Committee of the Board is the governing body. Acting under its authority, and in close union with it, is the Station Council composed of the following-named members of the College Faculty: President and Director, Agriculturist, Horticulturist and Botanist, Chemist, Meteorologist and Irrigation Engineer, Entomologist, and the Secretary of the Board of Agriculture. All the membes of the Station Council, save the first and last named, are heads of scientific departments in the College and as such perform a two-fold office—instructor and experimental worker. In each of these departments, there is at least one assistant engaged wholly in station work and paid altogether from the station fund.

It is the duty of the Station Council to prepare annually, usually in January or February, a schedule of experimental work, for the Home Station and the Substations, to be submitted to the Executive Committee for its approval. When thus approved, said schedule serves as a guide for all persons in any way connected with station work. The work of the Home Station is in the main scientific and possessed of permanent value. Certain records of that work appear in bulletin form and thus find their way to all parts of the country.

It has been suggested that our station work might be strengthened by so arranging class work in the scientific departments of the College as to give the chief officers therein more time and energy for experimental work. It is urged, with much force, that thorough station work necessarily calls for knowledge and skill of a

high order and that the best effort can not be put forth by those who have to do a large amount of teaching.

These suggestions naturally revive the oft-discussed question of the relations proper to exist between the College and the Experiment Station. It seems right to believe that, in the larger number of cases, the union of college and station work under one management brings the best results with the least outlay of effort and money. A well-equipped scientist can do, and direct, much teaching and experimental work, at the same time, if it is at all closely articulated. There is inexcusable waste in a plan that sends a worker from a class in algebra, to one in physics, and thence to a laboratory to engage in the analysis of soils, waters, or fertilizers; but waste is not apparent when the analytical worker gives a portion of his time to class-room and laboratory work in chemistry.

The question, after all, hinges on the ability and amount of the teaching and working force engaged. Give any of the heads of our scientific departments a proper working force and there will be no neglect of either college or station work. The total separation of the two kinds of work is not desirable in our institution. In our case, *union* brings economy with excess of strength.

The expenditure of the whole station fund upon the work of experimentation in progress at the Home Station will add very much to the amount and efficiency of that work. Three additional assistants of requisite scholarship and experience would give the experimental work now scheduled for the departments of Chemistry, Irrigation, and Entomology a rapid forward movement.

It is unwise to attempt the prosecution of many lines of experimental work at the same time. There is danger of attenuated results. Let us find out what is best worth doing and then do it with might and main. Again, the field chosen for experimental effort should be *domestic* rather than *foreign;* that is, our work should have some practical, close-in-touch relation to the great material interests of the State. What a vital question irrigation is to our people! How interested are our fruit-growers in everything that the entomologist can do

for the protection of their orchards! How instructive to the farmer, with unmarketable alfalfa and other stock-supporting products, are experiments in sheep and cattle feeding! How innumerable are the cases where the services of an analytical chemist are in high demand!

The completion of the new Chemical Laboratory will open the way for the rapid extension of the work of the Department of Chemistry, both in the way of college instruction and original investigation. Requests for chemical analyses come to us from all parts of the State. Some of these merit no more than respectful denial, since they are born of ignorance or prompted by selfish interests; others by reason of their relation to the general weal are worthy of prompt attention. I shall welcome the time when the resources we control will enable us to respond more readily to requests for analyses of soils, waters, and growths touching more intimately the farm life of our people. One reads with a feeling of regret this statement clipped from the columns of The Mining Industry—"There is nowhere any reliable analysis to be obtained of the water of any considerable number of Colorado springs. The State has more of them than any other in the Union. In a general way we know there are those which deposit iron oxides and sulphides, cinnabar, silica and probably all the alkaline metalloids. But no one has ever classified the leading ones to tell us whether they are alkaline, saline, acid, non-gaseous or carbonated, etc.

Coupled with Colorado's magnificent health-giving climate, these springs will some day make the State as famous as Baden-Baden is now."

I would like to see the fruit-growers of Colorado look with confidence to us for timely assistance in the management and preservation of their orchards. There should be opportunity for our station workers to visit any locality where personal observation is needed to acquire information precedent to intelligent planning of ways and means for helping the farming interests of that locality. The plan of sending a corps of workers, under the direction of our Irrigation Engineer, into the San

Luis Valley, last summer, to investigate the water supply of that portion of the State is a step in the right direction. The statement of results should follow a very thorough investigation, under a number of conditions; else injustice be done to some important interests in which the people of that region are deeply concerned. When college authority makes a report upon the resources of any part of the State, said report should present the *truth* no matter what selfish interests are unsettled thereby. The cost of the investigations made in the Valley thus far, is $321.90. There are sections of Colorado unknown, save by report, to some of our station officers. Some change of class requirements that would leave these workers free, at times, for personal investigation outside of college territory seems desirable. At least more advantage should be taken of the long vacation season in which to make such investigation.

The Governing Board has never used any portion of the experiment station fund for college support. The College employes who do station work receive no undue portion of their compensation from the the station fund. No raid is ever made on the treasury of the station but, on the contrary, its money is guarded with jealous care. It is within bounds to say that the experimental work now in progress costs quite a sum in excess of the revenue for experiment station support. The college revenue always makes good any deficit in the station fund.

The members of the Station Council have rendered valuable service in farmers' institutes the past year. Never less than two members of the Faculty are detailed for service at each institute. No requests for institute workers are refused. Sometimes, it is true, home work of a pressing character compels us to ask a change of the date of holding the institute; but, the change being made, the attendance of some of our representatives at the institute sessions follows. The College and Station were represented at institutes held at Boulder, Longmont, Brighton, Las Animas, Monte Vista, Loveland, Canon City, Delta, Fort Morgan, Gypsum, and Glenwood Springs.

There is reciprocal advantage in this institute work. Those who give instruction receive it as well. The *practical* man is led to see things from a new point of view, and the *theorist* is forced to bring his theories to the test of experience.

STATION WORKERS.

Herewith are given the names of all persons regularly connected with station work, the positions filled, and the salaries received:—

Home Station— Names and Positions.	Annual Salaries from Station Fund.	
Alston Ellis, Director	$ 1,000.00	
W. W. Cooke, Agriculturist	500.00	
C. S. Crandall, Horticulturist	500.00	
Wm. P. Headden, Chemist	500.00	
C. P. Gillette, Entomologist	500.00	
L. G. Carpenter, Meteorologist and Irrigation Engineer	500.00	
D. W. Working, Secretary Station Council	400.00	
ASSISTANTS.		
Frank L. Watrous, Agriculture	1,000.00	
Jacob H. Cowen, Horticulture	1,000.00	
Charles J. Ryan, Chemistry	900.00	
Emma A. Gillette, Entomology	300.00	
Robert E. Trimble, Meteorology	900.00	
Sub-Station Superintendents—		
Philo K. Blinn, Rocky Ford	800.00	
J. E. Payne, Cheyenne Wells	600.00	
Total of Salaries		$ 9,400.00

The yearly expense for labor is $2,600.

OUTLINES OF STATION WORK.

The schedules of station work for the year 1896 are herewith given for the reason that they properly form a part of the history of the Station for the year:—

AGRICULTURAL SECTION.

Farm Crops.

I. Testing of wheat on alfalfa sod compared with land in rotation.

II. Testing of oats and barley on alfalfa sod compared with land after sugar beets.

III. Testing of corn on fall as compared with spring plowing.

IV. Testing of corn on land manured with sheep manure compared with ordinary stable manure.

V. Testing of sugar beets on subsoiled land compared with land not subsoiled.

VI. Testing of varieties of cereals and forage crops.

Feeding Experiments.

I. Feeding pigs on alfalfa alone, alfalfa and a half ration of grain, alfalfa and a full ration of grain.

II. Feeding sheep on standing corn.

III. Raising early lambs on a commercial scale.

IV. Feeding steers on grain, ensilage, and sugar beets.

V. Feeding cows for milk on corn as compared with bran to accompany alfalfa hay and pasture.

VI. Continuing the tests of cold deep setting compared with the separator for a small dairy.

SECTION OF BOTANY AND HORTICULTURE.

I. The study of the *flora* of the State, special attention being given to:

1. The weeds of the farm and garden.
2. Grasses, native and introduced.
3. The various species and varieties of the *genera* Oxytropis and Astragalus.

II. The further introduction to the garden of such wild fruit plants as can be obtained.

III. Nursery tests of orchard fruits with a view to the study of the adaptability of varieties to this climate.

IV. Tests of varieties of small fruits.

V. Coöperative work with the Division of Forestry of the United States Department of Agriculture.

Under the first division of the schedule it is much desired that opportunity be afforded for an examination of the *flora* of the southern part of the State. There are several regions that have not been visited by botanists, and information concerning the characteristic plants of these regions is much needed.

Under the third division of the schedule, our lists of varieties of fruits that it seems desirable to add to the present collection, if filled, will involve an expenditure of about $150.

In connection with the test of varieties of fruits a series of experiments with different methods of grafting is in progress. It is also proposed to make a series of crosses between varieties of plums, and also between varieties of strawberries.

SECTION OF METEOROLOGY AND IRRIGATION ENGINEERING.

I. The Duty of Water:
  1. On a large scale, with the coöperation of canals.
  2. On different crops. This should be extended into different localities.

II. Investigation of losses in carriage by seepage and evaporation.

III. Return waters: continuation of previous investigations and verification of previous conclusions.

IV. Irrigation survey of the State.

Some work has been done in this line before, but it has had to give way both because of lack of funds and of time.

My desire in this connection is to continue a systematic investigation of the water resources of the State, their character, best mode of utilization; a study of the methods of irrigation, their faults and advantages. For this particular season, I propose to confine my work to the San Luis Valley; the special effort being a study of the sub-irrigation and sub-surface waters. Nearly all the work so far done falls into a part of this general plan.

Estimates: The continuation of all work but that named in No. 4, will cost about $175, including current expenses of various kinds—blanks, repairs, etc.

No. 4 for the whole season for the direct and indirect expenses will not require over $300.

A partial promise of Government aid, in carrying out the work named in No. 1, has been given.

If the work outlined in No. 4 is approved, it should begin before the irrigation season opens in order to secure

the co-operation of those who can furnish the desired information. This co-operation is needed from the beginning to the end of the irrigation season.

CHEMICAL SECTION.

I. Coöperative work with other Departments.

II. Work in connection with the Association of Official Agricultural Chemists, on fodders.

III. Experiments on the digestibility of the albuminoids of alfalfa hay to determine the relative value of new and old hay.

I. The Chemistry of Irrigation:

1. The composition of the ditch waters.
2. The amount that flows off the irrigated land.
3. The composition of this portion to see how much it takes up from the surface soil.
4. The amount of water that percolates to different depths and the composition of the respective portions.

II. A study of the effects of growing beets upon alkali land. This will embrace the following subjects:

1. The amount of water flowing into the alkalized area.
2. The character of the strata through which the waters move, together with the size of the area drained.
3. The change, if any, in the depth of the water level caused by irrigation of the area in question.
4. The rate of evaporation from the surface and the amount of alkali deposited.
5. The depth to which the alkalization takes place.
6. The effect on the composition of the soil.
7. The effect of beet growing upon the amount of alkali.
8. The composition of the beets as to feeding value and for sugar.
9. To determine whether a variety grown for tops only would not be better than varieties grown primarily for the roots yielded.

ENTOMOLOGICAL SECTION.

I. Collecting and rearing insects for the purpose of determining food-habits and life-histories.

II. Experiments for the destruction of insect eggs.

III. Experiments with the "Grasshopper Disease."

IV. Experiments to determine habits and remedies for "Woolly Aphis."

V. Testing new insecticides.

VI. Experiments for the destruction of miscellaneous insect pests.

VII. Experiments in the Apiary:

1. To determine the value of sugar as winter stores.
2. Testing apiary appliances.
3. Making a collection and list of native honey and pollen-producing plants with notes as to their possible value.
4. Experiments to determine the nature of and remedies for the disease known as "Bee Paralysis."

THE ARKANSAS VALLEY EXPERIMENT STATION.

ROCKY FORD, COLORADO.

AGRICULTURAL DIVISION.

I. *Cereals:*

1. Comparative test of the cost and profit in barley, wheat, and corn growing. Five acres each.
2. Test of the cost of production of corn on new alfalfa sod. Four acres.
3. Test of varieties—barley, wheat, corn, and oats—on alfalfa sod. Two acres.

II. *Grass and Hay Crops:*

1. *Clover*—Comparison of the merits of red and crimson clover as a hay and seed crop; also to test the merits of each for green manuring in the old orchard.
2. *Alfalfa*—Old wheat and corn land to be seeded to alfalfa, a portion of the field to be sown alone, the remainder to be sown with oats, to test the merits of seeding with and without grain; also to furnish feed for the station horses. Seven acres in all.
3. *Pasture*—Pasture tests, observations on present field of *Bromus inermis;* also to make an addition of three acres, sown to rye, timothy, and orchard grass. Six acres in all.
4. Tests—Plat tests of new and untried varieties on plats ½ acre each. One and one-half acres.
5. Irrigation—Record of the number of irrigations applied to clover, in comparison to alfalfa, on new seeding.

GARDEN DIVISION.

I. *Vegetables:*

1. Test of new and untried varieties with detailed reports on cultivation and adaptability to this climate. Two acres.
2. Cantaloupes on alfalfa sod, to test the cost and profit per acre; detailed record of cultivation and irrigation. One acre.
3. Sugar beets. Test of varieties and cost of production on alfalfa sod. One-half acre.
4. Potatoes on alfalfa sod; test by early and late planting of all the most promising varieties that can be secured. Four acres in all.
5. Miscellaneous planting for exhibition purposes. One-half acre.

HORTICULTURAL DIVISION.

I. *Old Orchard:*

1. Observations on the effects of summer and winter pruning; also on inflorescence, setting, and fruit yields.
2. Comparative tests of the methods of cultivating an orchard—clean cultivation, rye, red clover, crimson clover, and buckwheat for green manuring.

II. *New Planting:*

1. Apples, peaches, pears, cherries, plums and prunes. any new and untried varieties. Five or six acres.
2. Small fruits—strawberries, currants, gooseberries, raspberries, blackberries, and grapes.
3. Forestry—addition to nut, shade, and ornamental trees.
4. Hedge row tests of different kinds. Wind-break around the orchard.
5. Additions of ornamental shrubbery and improvement of lawn around station cottage.

IRRIGATION DIVISION.

I. Measurement of water applied to different crops.

II. Observations on the effects of water applied at morning, noon, and night, on a plat of garden peas, the results to be determined by the date of blooming and the yield. The three portions of the plat to be, otherwise, under the same conditions. Notes to be taken on the temperature of the water.

ADDITIONS APPROVED SEPTEMBER 21, 1896.

I. Grain Culture: Test of varieties to be conducted for a series of years with detailed reports:
   1. On plats for preliminary results.
   2. The more promising varieties to be carried to a more practical test on field areas of an acre or more. Both fall and spring varieties to be tested.

II. Winter Rye: To be sown as a station crop on land difficult to irrigate, to be seeded to alfalfa the first of May. Four acres.

SAN LUIS VALLEY EXPERIMENT STATION.

MONTE VISTA, COLORADO.

I. Experiments with grain on spring plowing:
   1. Sowing wheat on a plat on which the stubble has been burned, the land then being plowed shallow.
   2. Sowing wheat on plat deep plowed—8 or 10 inches—and then thoroughly rolled.
   3. Sowing oats on land, which was in oats last year, after irrigating and plowing.

II. Some experiments in small plats:
   1. Testing same varieties of early potatoes.
   2. Testing some varieties of grasses. Notes on small plats of grasses sown last season will be taken.

RAINBELT EXPERIMENT STATION.

CHEYENNE WELLS, COLORADO.

FARM DIVISION.

I. Wheat:
   1. Defiance. One acre.
   2. To be selected. One acre.

II. Oats:
   1. Excelsior. One acre.
   2. Black Russian. One acre.

III. Barley:
   1. Highland Chief. One acre.
   2. To be selected. One acre.

IV. Corn:
   1. White Kansas King. Four acres.
   2. Colorado White. Four acres.
   3. Queen of the Field. Four acres.
   4. White Australian. Four acres.
   5. Selected corn on trial plats.

V. Canes:

1. Egyptian Rice Corn. Two acres.
2. Milo Maize. Two acres.
3. Kaffir Corn. Two acres.
4. Sorghum. Two acres.

VI. Broomcorn: Three varieties. Six acres.

VII. Potatoes: Selected, on one and one-half acres.

VIII. Field Peas: Canadian, one-half acre.

IX. Beets: Selected, on one-fourth acre.

X. Grasses: Selected, on trial plats.

GARDEN DIVISION.

I. Small plats, selected vegetables including melons, pumpkins and squashes.

II. Trees:

1. Nineteen trees planted in the spring of 1895 have died.

	Planted.	Died.
Ben Davis	25	1
Winesap	10	0
Utter's Red	12	5
Missouri Pippin	3	2
Jeniton	12	1
Romanite	2	0
Bellflower	2	0
Grimes Golden	5	0
Red Astrachan	5	0
Russian Apricot	6	3
Early Richmond Cherry	12	2
English Morello Cherry	12	5
Total	106	19

2. Eight trees are lacking to fill out the plat under fence. Thus, to make good the loss of last year and to complete the planting of the plat, twenty-seven trees are needed.

STATION PUBLICATIONS.

Section 4, of the congressional act relating to experiment station begins as follows: "That bulletins or reports of progress shall be published at the said stations at least once in three months." The first bulletin

from the station was issued in August, 1887. The whole number of bulletins now in print is thirty-five.

No.	*Subjects.*	*Authors.*
1.	Reports of Experiments in Irrigation and Meteorology	Elwood Mead
2.	Report of Experiments with Grains, Grasses, and Vegetables on the College Farm	A. E. Blount
3.	Concerning the Duties of the Secretary of The State Board of Agriculture, and Distribution of Seeds	Frank J. Annis
4.	Report of Experiments with Potatoes and Tobacco	James Cassidy
5.	Experiments in the Apiary	C. M. Brose
6.	Notes on Insects and Insecticides	James Cassidy
7.	Potatoes and Sugar Beets	James Cassidy David O'Brine
8.	Alfalfa: Its Growth, Composition and Digestibility	David O'Brine James Cassidy
9.	Soils and Alkali	David O'Brine
10.	Tobacco	David O'Brine James Cassidy
11.	Sugar Beets	C. L. Ingersoll David O'Brine
12.	Some Colorado Grasses and their Chemical Analysis	David O'Brine James Cassidy
13.	On the Measurement and Division of Water	L. G. Carpenter
14.	Progress Bulletin on Sugar Beets	David O'Brine
15.	The Codling Moth and the Grape-Vine Leaf-Hopper	C. P. Gillette
16.	The Artesian Wells of Colorado and their Relation to Irrigation	L. G. Carpenter
17.	A Preliminary Report on the Fruit Interests of the State	C. S. Crandall
18.	Index Bulletin	W. J. Quick
	Special Bulletin "A" Concerning Subjects Investigated by the Experiment Station	
19.	Observations upon Injurious Insects, Season of 1891	C. P. Gillette

20.	I. The Best Milk Tester for the Practical Use of the Farmer and Dairyman..........	W. J. Quick
	II. The Influence of Food upon the Pure Fat Present in Milk........................	W. J. Quick
21.	I. Sugar Beets......................	F. L. Watrous
	II. Irish Potatoes......................	F. L. Watrous
	III. Fruit Raising......................	F. L. Watrous
23.	Colorado Weeds............................	C. S. Crandall
22.	A Preliminary Report on the Duty of Water.	L. G. Carpenter
24.	A Few Common Insect Pests..................	C. P. Gillette
25.	Progress Bulletin on the Loco and Larkspur..	David O'Brine
26.	Garden Notes for 1893............	Marion J. Huffington C. S. Crandall
	Farm Notes for 1893................	W. W. Cooke Frank L. Watrous
	Seeding, Tillage, and Irrigation..............	Fred. Huntley
27.	The Measurement and Division of Water. (Third Edition, Revised, of Bulletin No. 13)..........	L. G. Carpenter
28.	The Russian Thistle........................	C. S. Crandall
29.	Strawberries and Grapes: Notes on Varieties............	
30.	I. Farm Notes for 1894............	W. W. Cooke Frank L. Watrous
	II. Notes on Tomatoes...............	Marion J. Huffington
31.	Hemiptera of Colorado..................	C. P. Gillette Carl F. Baker
32.	Sheep Feeding in Colorado..................	W. W. Cooke
33.	Seepage or Return Waters from Irrigation..	L. G. Carpenter
34.	Cattle Feeding in Colorado..................	W. W. Cooke
35.	Alfalfa................................	Wm. P. Headden

Bulletin No. 35 is now in press. It would have been distributed ere this but for the printer's slow movements. The close of the year again finds us short of the required number of bulletins. The amount of *matter* presented in the three bulletins, issued within the year, is more than sufficient, if divided, to fulfill the statutory requirement before quoted. I think it advisable to issue a bulletin just as soon as investigation secures anything of value, without waiting for the preparation of *everything* that may properly relate to its title. Bulletins are like reports. It is not always the longest that contains the most.

The Eighth Annual Report of the Station was printed as a part of the Seventeenth Annual Report of The State Board of Agriculture. The Station report covered about 100 pages. Its cost, for an edition of 1,500 copies, was $100. Bulletin No. 33 contains 64 pages. An edition of 8,000 copies cost $330.55. There are 36 pages in Bulletin No. 34. The cost of the edition of 6,000 copies was $135.40. The cost of Bulletin No. 35—8,000 copies—will not be less than $600. It will contain at least 100 pages of printed matter and, in addition, 14 pages of plates. The half-tones printed upon selected paper and the necessary tabular work swell the cost to the sum named.

CONCLUSION.

In the preceding pages I have tried to set forth the present condition of the Experiment Station. I am of the opinion that the lines of work attempted should be drawn within narrower limits. A worker becomes lost in a large field, within which widely divergent operations may be going on. We speak of "intensive farming," and have a pretty clear idea of the meaning of the words. I would have that idea take possession of those who direct the progress of most of our station work. That work should be both scientific and practical—should be prosecuted by those able to plan and execute something original and join the product of such original investigation to the practical operations of the farm in a manner to render them more far-reaching in good results. The scientist seeks out principles and reasons with the purpose of making them serviceable in some work in progress, or needed. He needs to know conditions before he can hope to make his efforts available for modifying them. Here is where some weakness in station work is made apparent. Experimental work at the Home Station may be highly suggestive to farmers in northern Colorado but may be much less so to those working amid conditions quite different. Even should the substation management be continued under State patronage, it seems to me desirable to have other work, co-operative with that of the Home Station, in progress in other locali-

ties in the State. The cost of this co-operative work would be but trifling, being chiefly the expense of its inception and subsequent inspection by some station officer. As soon as some definite understanding is reached with reference to the future of the sub-stations, experimental work will be prosecuted with more certainty and with better outcome.

Respectfully submitted,

ALSTON ELLIS,

Director.

Fort Collins, Colorado,
December 9, 1896.

REPORT

OF THE

AGRICULTURAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I have the honor to present herewith the annual report of the experimental work done by the Agricultural Section of this Station.

The work has gone on with but little interruption. The results have in the main been fairly successful. The nearest to a failure in the experiments was in the case of the sugar beets that were badly injured by the severe hailstorms of the early summer.

In cereal crops tests were made of wheat, oats, and barley the second year from alfalfa sod as compared with similar contiguous land that had not been in alfalfa. In each case the alfalfa sod produced much the better results; with wheat as 100 to 90; with oats as 100 to 60, and with barley as 100 to 45.

Tests were made with wheat from hand-picked seed and yielded some very fine grain running over forty bushels to the acre.

The work of the previous year was repeated on corn grown from seed that had been raised in various altitudes and latitudes. For the production of grain, the seed from Colorado has given as good results as that from any other state, but for growth of fodder for ensilage purposes, corn from a lower altitude and latitude has proved superior.

The third season's experiments on the use of ensilage are now in progress. It is yet too early to tell what will be the final verdict on ensilage in Colorado. The past two winters' feeding has, however, definitely settled the question for us of its adaptability for steer feeding. It has proved valueless for that purpose when the steers are fed outdoors in cold weather. It does not seem probable that any future work will change this conclusion. The above remarks apply both to corn ensilage and to ensilage made of alfalfa. It has been a favorite idea that alfalfa alone or alfalfa and corn together would make a perfect ration. This is frequently advocated by those who have never seen alfalfa ensilage and especially by those who have never lived in an alfalfa country.

If the process of ensilaging has value, this value must lie in one or more of three results. It must preserve the fodder more perfectly, or it must increase its palatability, or it must so prevent loss that the dry matter of the ensilage has greater feeding value pound for pound than that of the dry fodder. Alfalfa ensilage fails in all these particulars. Though the results of the investigations of the Chemical Department of this Station show enormous losses in curing alfalfa and handling it in the dry state, yet they are scarcely larger than the losses by fermentation in the silo. Stock eat dry alfalfa readily and greedily, so that making ensilage of it cannot increase its palatability; while our tests show that there is no gain in the feeding value of the matter itself. With no positive benefits, there is an increased cost of labor in filling the silo and feeding out the contents, that more than doubles the cost of feeding any kind of stock on alfalfa ensilage as compared with dry alfalfa from the stack.

There remains yet to be solved the question of the feeding of corn ensilage to sheep and milch cows. Some work done last winter seems to indicate that ensilage is a profitable feed for stock sheep and it is being repeated this winter as also are our former tests on ensilage to milch cows.

Some forage crops grown the past season have given very good results. This was especially true of the millets of which the Japanese stood about four feet high with very large seed heads and yielding nearly twenty-five tons of green forage per acre, equivalent to about six tons of well-cured hay. African millet yielded a still greater weight of forage on stalks six feet high, but the yield of grain was less and the grain shattered badly. The millets were sown May 25 and harvested the middle of September. These yields are larger than any we have previously obtained and seem to be due in large measure to the use of water in irrigation and to irrigating late in the season. The same general results were obtained with some new ensilage corns. One in particular, the "Giant Mexican June," produced stalks eight inches in circumference and at twelve feet high, the first of October, were just beginning to show a tassel and no sign of an ear. The yield was forty-two tons of green fodder per acre. The fall of 1896 was quite favorable to the growth of such crops and the above results are probably higher than could be generally expected.

The work in dairying has been carried out on the same lines as indicated in previous reports. The results so far obtained seem to indicate that the claims of separator manufacturers as to their advantage in a small dairy are not valid. The work is now being repeated before the results are published.

The series of feeding experiments with milch cows, begun some time ago, is still in progress. These experiments have for their general object the determination of how much alfalfa can profitably be fed to a cow; or, to put it in another way, whether there is anything else that can be profitably fed to take the place of part of the alfalfa.

Alfalfa is particularly rich in muscle or flesh forming material and rather poor in the heat or fat producing elements. The corn plant in all its parts, as well as sugar beets and the grain of oats and barley have the opposite properties. All book rules for animal feeding claim that a mixture of these two classes of foods will

give better results than either separately. Yet Colorado farmers largely feed wheat bran with their alfalfa instead or corn meal and good results have been reported from the feeding of cottonseed meal with alfalfa—a ration entirely at variance with all standards. It seems desirable that extensive tests be made to determine the reasons for the different results obtained by eastern and western feeders.

The experiments with sheep have been continued the past year and are still in progress. In connection with the Department of Zoölogy and Entomology some extensive tests have been made this fall on the dipping of sheep for the cure of scab. The results will be published by that Department in the near future in bulletin form.

The work of previous years in cattle feeding was continued last winter and the results embodied in Bulletin No. 34, of this Station, on "Cattle Feeding."

A bulletin on the "Birds of Colorado" will be ready for the press by the end of December.

Other work in feeding has made satisfactory progress during the year both in hog feeding and in the raising of spring lambs.

Especial attention has been and is being paid to the growth and feeding of barley with the expectation of making that the subject of the next bulletin from this Section.

One of the most interesting experiments of the year is in connection with the "Idaho Coffee Pea." This has been grown on the farm the past two years and has demonstrated its ability to make a large growth with plenty of water and a fair growth with a very limited supply. It belongs to the pea family; is grown in rows thirty inches apart and the plants six to twelve inches apart in the rows. Its growth on the farm indicates that it can be raised for about one cent per pound.

The taste is a very good imitation of true coffee. One would easily get to liking the taste of the pure Coffee Pea, but it would generally be used mixed half and half with real coffee.

A test was made a few days ago in the Department of Domestic Economy of this College on its merits compared with that of the best grade of pure coffee that could be found in the Fort Collins markets. Six members of the College Faculty scored the beverage, without knowing the source of any of them and the average score was ninety-seven for half coffee pea and half coffee as against one hundred for pure coffee.

Respectfully submitted,

W. W. COOKE,

Agriculturist.

Fort Collins, Colorado,

November 30, 1896.

REPORT

OF THE

SECTION OF BOTANY AND HORTICULTURE.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I have the honor to submit the following report on the work in charge of the Section of Botany and Horticulture:

Fruits.

Apples—The nursery which now contains trees one, two, and three years old is divided into two blocks, one located on low and naturally moist land under the Town Ditch; the other on higher and drier land watered from the No. 2 Ditch. The soil of both blocks is a clay loam, but that on the low land is black and heavy, while on the higher block it is lighter and easier to work. The apparent differences in the behavior of the trees on the two blocks seems, however, to be due more to prevailing differences in the amount of water present in the soil than to the character of the soil itself, or to other differences in the two locations.

In a previous report the injury from the extreme low temperatures of the winter of 1894-'95 was remarked upon. The greatest injury was done to the trees upon the low land and this was attributed to insufficient ripen-

ing of the late growth induced by the naturally moist soil. On the higher land the trees made less growth, but ripened better and showed less injury. During the winter of 1895-'96 the conditions were very different. There were no protracted periods of low temperature, very little moisture in the form of rain or snow, and an unusual amount of warm dry wind. For a great portion of the winter the soil was free from frost. Evaporation was continuous, reducing the soil moisture on the high land until there was not enough to supply the demands of the trees. Under these conditions the effects noted for the preceding winter were here reversed.

The trees on the low land escaped injury, while those on the dry ground suffered severely. The injury was manifest early in the spring in the shriveled trunks and branches of many of the trees. Young trees showed greater injury than did the older ones; some of the latter losing only the tips of the branches, but even these showed in the small growth made during the summer that their vitality had been much impaired. Had water been available for a thorough irrigation late in the fall it is probable that the injury would have been less, but I do not think it would have entirely prevented it. Shrubs and ornamental plants on similar soil that was thoroughly saturated by irrigation in November showed marked injury of the same character as shown by the apple trees.

As grown under the conditions above outlined there is no warrant for final judgment as to the hardiness of the varieties represented, or as to their adaptability to our climate, but for a comparison of the relative behavior of the varieties, and for convenience, we have classified those which have passed through two winters under three divisions, and enumerate them below as Hardy; Half-Hardy; and Tender. The first division includes those varieties showing only slight injury or none at all. The second, those that have killed back partially, but not to the extent of rendering the injury permanent. The third, those that have suffered severely, and do not give promise of recovery.

HARDY

ON LOW LAND.

Duchess.
Early Colton.
Fink.
Gano.
Gravenstein.
Isham Sweet.
Jonathan.
Lissof Seedling.
Mann.
Pewaukee.
Tetofsky.
Walbridge.
Wealthy.
White Winter Pearmain.
Willow Twig.
Wolf River.
Wyeth.
Yellow Transparent.

ON HIGH LAND.

Bailey's Sweet.
Ben Davis.
Dyer.
Gideon's Best.
Gill's Beauty.
Golden Sweet.
Large Striped Pearmain.
Maiden's Blush.
Martha Washington.
Minkler.
Newtown Pippin.
Nickajack.
Red Limbertwig.
Western Beauty.
White Bellflower.

HALF HARDY.

ON LOW LAND.

Aikin.
Alexander.
Arkansas Black.
Autumn Strawberry.
Beauty of Kent.
Benoni.
Big Romanite.
Buncombe.
Chenango
Coffelt.
Colvert.
Cullasaga.
Early Harvest.
Early Red Margaret.
Early Strawberry
Fameuse.
Gideon.
Haas.
Indian.
Iowa Blush.
Little Romanite.
Lowell.

ON HIGH LAND.

Benoni.
Borsdorfer.
Buckingham.
Colvert.
Cooper's Market.
Delaware Winter.
Domine.
English Golden Russet.
Grimes' Golden.
Key's Winter.
King.
Kossuth.
Nelson's Sweet.
North-Western Greening.
Northern Spy.
Rankins.
Rhode Island Greening.
Salome.
Shiawassee.
Stark.
Vandevere.
York Imperial.

ON LOW LAND.

McIntosh Red.
McMahon.
Mammoth Black Twig.
Milam.
Ohio Nonpareil.
Plumb's Cider.
Price's Sweet.
Rawle's Janet.
Red Astrachan.
Red Winter Sweet.
Roman Stem.
Seek-No-Further.
Shackleford.
Shockley.
Summer Queen.
Sweet Bough.
Talman's Sweet.
Vandevere.
Wagener.
Winesap.
Yellow Transparent.

TENDER.

ON LOW LAND.

American Golden Russet.
American Summer Pearmain.
Arkansas Beauty.
Autumn Swaar.
Belmont.
Blue Pearmain.
Brightwater.
Carolina Striped June.
Clayton.
Cooper's Early.
Crawford Pippin.
Early Pennock.
Fall Pippin.
Grindstone.
Huntsman.
Ingram.
Keswick.
Lady.

ON HIGH LAND.

Autumn Swaar.
Brightwater.
Enormous.
Garden Ball.
Hatcher's.
Kinnard's Choice.
Langford.
Longfield.
Lord Nelson.
Loy.
N. Carolina Limbertwig.
Painted Lady.
Smokehouse.

ON LOW LAND.

Missouri Pippin.
Monmouth Pippin.
Peck's Pleasant.
Rainbow.
Rambo.
Red Bietigheimer.
Red June.
Red Winter Sweet.
Rome Beauty.
Shannon Pippin.
Smith's Cider.
Sops of Wine.
Spitzenburgh.
Summer Rose.
Twenty Ounce.
Utter's Red.
Winter May.
Yellow Bellflower.
Yellow Horse.

The tract of farm land covering 6-½ acres which was transferred to this department last spring for orchard purposes was given thorough preparation, and about five acres were planted with two year old station grown trees. The number of trees set was 480, representing 140 varieties. The work of planting was commenced as soon as it was known that water was available, but soon after starting the water was shut out and remained out for two weeks. All the hose obtainable was brought into use, and the trees within reach of the hydrant received water, but a few rows beyond reach got none until water was again turned into the ditch. These rows show many vacancies and will be replanted in the spring.

The soil in this orchard seems well adapted to the growing of trees, and with an assured water supply a fair test of the varieties under trial would be afforded, but the unusually scant supply of the past season made the starting of the orchard somewhat unsatisfactory. On the eighth of April there were shipped from the station nursery, for trial at the Rocky Ford sub-station 233 trees representing 77 varieties.

Pears.

The following varieties are now represented in the station nursery:

Bessemianka.
Buffum.
Clapp's Favorite.
Edmond's.
Idaho.
Keiffer.
Lawrence.
LeConte.
Louise Bonne of Jersey.
Mount Vernon.
Vicar.

An equal number of scions of each variety was grafted on French pear stocks, and on Quince stocks, and the trees have grown in contiguous rows in the low land nursery. None of the varieties named have done well on the Quince stocks. The dwarfing action of the stock seems to have gone beyond the limit of healthy growth, and the trees present a stunted and sickly appearance. On pear stocks the growth of all varieties has been good, but the Clapp's Favorite exceeds them all in vigor and appearance. All varieties were slightly injured by the low temperature of the winter of 1894-'5, but made a good growth the following summer, and came through last winter without injury.

Plums.

The old plum orchard contains the following varieties.—

Coe's Golden Drop.
Forest Garden.
Little Blue Damson.
Marion.
Miner.
Prairie Flower.
Russ No. 2.
Wolf.

All have been in fruit for several years. We have no record of the age of the trees, or of their origin. All appear perfectly hardy. Coe's Golden Drop is an excellent plum of English origin, but is unproductive here. Of the other varieties, Wolf is the most productive and, although not of the best quality, is the most profitable for this section. A severe hailstorm on June 5th, did considerable damage to foliage and fruit.

In the spring of 1894 the orchard was extended south to the banks of the Town Ditch. In this addition are 13 rows containing 227 trees which represent 76 varieties.

Most of the trees were obtained from the East Shore Nurseries of J. W. Kerr at Denton, Maryland. A few were station grown from scions obtained from various sources.

A number of varieties flowered and set fruit this season, but owing to the hail of June 5th, ripe fruits were obtained from only four varieties, namely—Weaver, Speer, Cheney, and LeDuc.

In the matter of hardiness the trees exhibit all degrees, from perfectly hardy, to very tender and unsuited to our conditions. Classified on the basis of hardiness into the three classes—Hardy—Half-Hardy—and Tender, the varieties fall into groups as below. Each class is divided to indicate the species from which the variety is derived, and the place of origin is given where known.

HARDY.

Prunus Americana.

- American Eagle, Missouri.
- Cheney, Wisconsin.
- Deep Creek, Kansas.
- Forest Garden, Iowa.
- Hawkeye, Iowa.
- Joe Hooker, ...
- Minnetonka, Minnesota.
- Ocheeda, Minnesota.
- Rockford, ...
- Rollingstone, Minnesota.
- Speer, Iowa.
- Weaver, Iowa.

Prunus Americana mollis.

- Van Buren, Iowa.
- Wolf, Iowa.

Prunus hortulana Mineri.

- Idol, Illinois.
- Miner, Pennsylvania.

Prunus pumila.

- Maryland.

Prunus domestica.

- Little Blue Damson, Foreign.
- Moldovka, Russian.
- Moore's Arctic, American.
- Silver Prune, Foreign.

Not classified.

- Comfort.

HALF HARDY.

Prunus Americana.

- Apricot, ...
- Colorado Queen, ...
- Harrison, ...
- Ida, Illinois.
- Illinois Ironclad, Illinois.
- Kampeska, ...
- Le Duc, Minnesota.
- Leonard, ...
- Maquoketa, Iowa.
- Moon, ...
- Peffer's Premium, Wisconsin.
- Winnebago, Minnesota.
- Kopp, Minnesota.
- Wyant, Iowa.
- Yellow Sweet, Minnesota.

Prunus hortulana.

- Clark, Maryland.
- Garfield, Ohio.
- Kanawha, Georgia?
- Missouri Apricot, Missouri.
- Southern Beauty, ...
- Whitaker, Texas.
- World Beater, Tennessee.

Prunus hortulana Mineri.

- Prairie Flower.

Prunus Maritima.

- Bassett, New Jersey.

Prunus triflora.

- Burbank, Japan.
- Ogon, Japan.

Prunus Simonii. China.

Prunus domestica.

- Bradshaw.
- German Prune.
- Lombard.
- Saratoga.
- Shropshire Damson.

Not classified.

- Champion.
- Hammer.
- Hattie.
- Holt.
- Spanish King.
- Trabasche.

TENDER.

Prunus Americana.

- Cottrell, Minnesota.
- Hill Top.
- Honey.
- Purple Yosemite.
- Quaker.
- Wild Rose.

Prunus hortulana.

- Choptank.
- Smiley.
- Poole's Pride, Illinois.

Prunus hortulana Mineri.

- Clinton, Minnesota.
- Forest Rose, Missouri.
- Indiana Red, Indiana.

Prunus chicasa.

- El Paso, Texas.

Prunus domestica.

Spaulding. Minnesota, Sweden.

The orchard has been given clean culture during the summer. As a protection against "frost cracks" the trunks of all young trees have been wrapped with burlap.

Scions of two of the Japanese varieties Ogon and Burbank top-grafted in 1894, the Ogon on wild Prunus Americana, the Burbank on Prairie Flower, fruited in 1895 and again this season. Two other varieties top-grafted on Prairie Flower fruited this season. Yellow Aubert, introduced from Russia, and the German Prune, both of the domestica class. These are all desirable varieties deserving further attention.

Small fruits.

The block of small fruits was increased last spring by the addition of a number of the newly introduced varieties. The plantation now embraces the following—

BLACKBERRIES.

Red.
- Marlboro.
- Golden Queen.
- Cuthbert.
- Turner.
- Royal Church.

Black cap.
- Hilborn.
- Kansas.
- Carman.
- Gregg.

Purple cane.
- Shaffer.

GOOSEBERRIES.

Oregon Champion.
Smith's Improved.
Industry.
Houghton.
Downing.

RASPBERRIES.

Ancient Britain.
Ohmer.
Eldorado.
Snyder.
Agawam.
Erie.
Stone's Hardy.
Wilson's Early.
Wilson Jr.

CURRANTS.

Raby Castle.
North Star.
Victoria.
Red Dutch.
Fay.
Cherry.
Versaillaise.
White Grape.

Strawberries.—

The number of varieties now represented on the station grounds is 73; of these 55 were in fruit this season. The qualities of about half of the fruiting varieties

were noted in bulletin No. 29, but for comparison with new introductions, and for still further trial, most of them are still retained. Of the varieties reported upon all but three maintain the estimate placed upon them. The Wolverton, Gandy, and Loudon which received favorable mention did not do well this season; the plants made but small growth, and were unproductive. The early varieties under trial were damaged to some extent by late frosts, and the product of all varieties was materially diminished by the destructive hail of June 5th.

A tentative classification based upon productiveness and vigor of growth as observed this season, into groups which we may call Good, Medium, and Poor, would separate the varieties as listed below.

Good.	Medium.	Poor.
Bederwood.	Barton.	Atlantic.
Belle of LaCrosse.	Beverly.	Bessie.
Captain Jack.	Boynton.	Bubach.
Crescent.	Cornelia.	Gold.
Cumberland.	Eureka.	Greenville.
Edward's Favorite.	Glendale.	Mark.
Edgar Queen.	Gandy.	Mrs. Cleveland.
Enhance.	Gov. Hoard.	Ontario.
Jessie.	Gypsy.	Timbrell.
Louise.	Haverland.	VanDeman.
Luella.	Ironclad.	Westlawn.
Parker Earle.	Jumbo.	
Pearl.	Lady Rusk.	
Stayman's No. 1.	Leader.	
Summit.	Lida.	
Warfield.	Loudon.	
	Lovett.	
	Manchester.	
	Monarch.	
	Princess.	
	Puritan.	
	Shuster's Gem.	
	Seedling of Downing	
	Thompson.	
	Tippecanoe.	
	Wilson.	
	Wolverton.	
	Yale.	

We here have 16 varieties in which good qualities predominate, and which have been sufficiently tested to warrant recommending them for planting. Parker Earle—Warfield—and Edward's Favorite head the list for *both* home use and market. Crescent and Captain Jack are valuable particularly as market berries. For home use only we consider Louise as the best, with Belle of La-Crosse and Cumberland next.

The 28 varieties rated as medium are by no means condemned, but none of them have for this season shown productiveness and vigor sufficient to warrant an unqualified recommendation. Further trial is needed before judgment is passed upon them.

The varieties classed as poor, 11 in number, do not seem suited to our conditions. Most of them came to us highly recommended, and in some localities they undoubtedly do well, but their behavior here warrants the rating as poor.

The following 18 varieties are recent acquisitions whose fruiting qualities have yet to be tested.

Annie Laurie.	Hatfield.	Longworth Prolific.
Aroma.	Hersey.	Margaret.
Bisel.	Ivanhoe.	Murray.
Brandywine.	Jay Gould.	Phillips.
Brunette.	Jucunda Improved.	Rio.
Cyclone.	Lady Thompson.	Tennessee Prolific.

With a view to the production of new varieties some work in crossing has been attempted. Pollination was performed on 124 flowers, and from these were obtained 88 perfect fruits, and 21 imperfect fruits. As the result of these crosses we now have growing about 500 seedling plants. There are also 39 strong seedlings derived from crosses effected in the greenhouse during last winter.

Grasses.—

During the past six years plat culture of grasses and forage plants has each year received some attention. There have been tested about 150 native and introduced species. Some that are valued in certain portions of the world prove weedy and worthless here, while others are as plainly of value for either pasture or hay, or for both.

The extension of the Mechanical Engineering Building last spring made the removal of most of the old plats necessary. New plats to the number of 36 were added in which were sown seeds sent us for trial by the Division of Agrostology of the U. S. Department of Agriculture. Some of these had been previously grown, and some were new.

Through the courtesy of Mr. George H. West of Greeley we received late in the summer, small packets of seeds of 75 species from the house of A. Le Coq and Co. of Darmstadt, Germany. It is the intention to sow these in the spring.

Herbarium specimens of all species grown have been preserved, and about 50 species have been photographed to record peculiarities in habit of growth. The accumulated notes on these grasses will be brought together for presentation in bulletin form as soon as possible, but I desire to record here the notes on a few of the species that have been tried, with our estimate of their value.

Eleusine coracana Gærtn.—African Millet.

An annual grass native in India, Africa, and South America. In both India and Africa it is cultivated for forage and also for the seed, from which a flour is made that constitutes an important part of the food of the poorer classes. The plants are rather coarse in habit; the stems are flat, leaves ample, and the digitate, many-flowered spikes produce seed in abundance. Seed was sown May 2; the plants reached a height of 20 inches, were in bloom August 20, and ripe by September 15. Our first experience with this grass was in 1890 when small plats were grown, with, and without irrigation. It showed ability to resist drouth, and without water grew 12 inches high and produced seed. On the irrigated plat the plants were double the height with a corresponding increase in leaves. Plats grown in 1891 and 1892 from seed raised here showed a marked diminution in the size of the plants. The grass will not stand pasturing, and the bulk of forage produced does not commend it as a hay grass.

Two other species of this genus—Eleusine Ægyptica and Eleusine Barcinœnse, were grown, but neither developed economic qualities equal to the species coracana.

Diplachne imbricata (Thurb.) Scribner.

This is an annual native in New Mexico and Arizona. Stems numerous 6 to 18 inches long, a few of them ascending, but the greater number prostrate. Growth slow, the plants not coming on flower until September. It does not appear to be of any value.

Festuca duriuscula L. Hard Fescue.

Seeds of this grass sown last spring did not germinate, but as we have grown it in previous years it may be mentioned here. It is found in the parks and mountain meadows of the northern part of the State at altitudes of from 7,000 to 10,000 feet in company with the Sheep's Fescue—Festuca ovina, apparently native. It is distinguished from the Sheep's Fescue by its taller and more robust growth, and its more open panicle. Under plat cultivation it grows two feet high, and produces a thick mass of radical leaves; it is somewhat stoloniferous, and maintains its character as a "bunch grass." We regard it as valuable for pasture.

Muhlenbergia glomerata Trin.—Spiked Muhlenbergia.

This grass is a native of Colorado. It is common in moist meadows, along streams, and on ditch banks. In some localities it forms a considerable portion of the hay from native meadows. The stems are erect, about two feet high, very leafy. During this season, and in previous seasons, as grown on the station plats it has shown the qualities of a good hay grass, and the commonly expressed opinion that it is valuable seems fully confirmed.

Muhlenbergia sylvatica Torr. Wood Muhlenbergia.

This grass is also a native, but less common than the preceeding and inhabiting drier situations. It is slender, rather diffuse, about 20 inches high, yielding a small amount of forage, and is apparently of little value.

Panicum miliaceum L. Common Millet.

A coarse, leafy grass two feet high. It grows rapidly and ripens early. It makes an excellent green food for cattle, and for this use should be cut when the plants are in bloom. When over-ripe the stems become hard and are of little value. It is of Asiatic origin and was anciently cultivated for the seeds which served as an article of food.

Panicum Texanum Vasey. Texas Millet or Colorado Grass.

This is an annual, native in Texas where is it prized as a hay grass. As grown here the stems are from 8 to 20 inches long, decumbent, rising only a few inches above the ground. The leaves are short, broad, and very abundant. It promises nothing as a hay grass, but being strongly resistant to drouth may be valuable in pasture mixtures. It produces an abundance of seeds, and will doubtless prove persistent by self-seeding when once established.

Panicum Crus-galli L. Barnyard grass.

A very coarse annual introduced from Europe and widely distributed. Under plat culture is made a strong growth two feet high. While it is grown in the south to some extent as a hay grass we look upon it here as a weed. It is not uncommon on ditch banks and in waste places.

Eragrostis Abyssinica Schrad. "Teff." "Hay Grass."

This grass was introduced from Abyssinia by the U. S. Department of Agriculture several years ago and distributed for trial. Reports of its behavior have been favorable. It has been grown on the station plats for two seasons, and we rank it as one of the best introduced grasses. It grows about 2½ feet high and produces an abundance of very long leaves. It is an annual and must be sown each year, but its erect habit and the large amount of forage produced recommend it as worthy of more extended trial on larger areas.

Andropogon nutans L. Bushy Blue Stem. Wood Grass.

A native perennial not uncommon in the natural meadows of the lower mountains, and along the streams on the plains. It is nutritious and acceptable to stock if cut before the stems ripen and become hard. We have sown the grass twice in previous seasons, but in both cases the seed failed to germinate. This season an even stand was secured. The growth was slow, and mainly confined to the production of radical leaves no flowering stems were formed. Late in the season the tendency to tiller was marked, and as the root systems are ample the plants seem prepared to make a strong growth next season. From observations on the wild plants I conclude that the species would not be a profitable one to sow alone, but at an ingredient of a mixture for moist meadows I think it has value.

Bromus unioloides (Willd.) HBK. Schrader's Brome Grass.

This grass has been grown on the station plats for four seasons. It is an annual of rather coarse habit yielding a fair amount of forage. It starts late in the spring and at first grows slowly, later the growth is more rapid, reaching a height of two feet, and blooming the first week in July.

Bromus inermis Leyss. Hungarian Brome Grass. Awnless Brome Grass.

Of all the introduced grasses grown on the station plats during the last five years this is the most promising. It is a strong growing perennial, but is finer, and has less of the rank weedy character than any other species of the genus that we have tried. It is among the first to start in the spring, and is the last to lose its green color in the fall. Extreme winter temperatures have no injurious effect, and it stands drouth remarkably well.

The flowering culms have an average height of 2½ feet, and the mass of leaves is about two feet high. The two features that most highly commend the grass are, its strong tillering power, and the abundance of the very

long leaves. While yielding a fair amount of hay, the qualities mentioned recommend it most strongly as a grass for permanent pastures. It is very persistent because of the abundant production of long underground stems, and this might make it objectionable when sown upon land used for rotation. The grass has been tried in many places and is generally regarded with favor.

Two species of Perennial Rye Grass—Lolium perenne L. and Lolium Italicum A. Br., both introduced from Europe, have been grown for several years. Both develop good qualities as pasture grasses.

In England they are valued as hay grasses, but their habit here does not indicate a sufficient crop to be profitable. They cover the ground with a thick mat of leaves, and recover quickly after mowing or grazing. Both start early and remain green until late, and we believe they could be used to advantage in pasture mixtures.

The genus Poa has been represented on the plats by several species, all natives of Colorado, and their behavior deserves mention. They are all fine, slender stemmed grasses, not so well adapted for hay as for pasture. The species making the strongest growth is the well known June Grass, or Kentucky Blue Grass—Poa pratensis—which covers the plat thickly with a leafy growth. It spreads by underground stems and is thus able to maintain itself even under adverse conditions. Its value as a pasture grass is recognized everywhere, and as a lawn grass it has no superior.

Poa serotina Ehrh. Fowl Meadow-Grass.

This is found along streams, and in moist native meadows. It is distinctively a moist land grass, and under plat culture quickly shows the effect of drouth. It produces no underground stems and unless in soil continually moist will soon be superseded by other grasses.

Poa tenuifolia Nutt.

Very common in the foothills and lower mountains. It does not form a sod, but grows in bunches, constituting a considerable portion of the forage on mountain

ranges. The leaves are usually short, and the stems slender and it seems to offer nothing of value under cultivation.

Poa nemoralis L. Wood Meadow-grass.

This species inhabits moist, and particularly shady spots along streams. It is very delicate in appearance, and on our plat grew to a height of from 12 to 15 inches, but does not produce forage enough.

The other species of Poa grown on the station plats were, Poa arida Vasey, Poa alpina L., Poa lævis Vasey, Poa reflexa V. & S., and Poa cuspidata Nutt; all of which are too small and delicate to be regarded as valuable for cultivation.

Of other native grasses grown I will here mention but one: the Rough Fescue, also called "Montana Bunch Grass," Festuca scabrella Torr. This is a mountain grass common at altitudes of from 8,000 to 10,000 feet.

It forms large bunches, often a foot in diameter, which commonly die at the center. Few stems are produced, but the long radical leaves are abundant, and are much relished by both horses and cattle. Under plat culture it grew vigorously, fully maintaining the characters developed in its native home. It does not stand drouth well, but in favorable locations would be a valuable addition to the pasture grasses. The main difficulty would be in obtaining seed sufficient for a start, as the plants produce it very sparingly.

Herbarium.

Very little time has been available for prosecuting the work of collecting. The most extended trip of the season was one of ten days' duration to the foot of the main range directly west of Fort Collins. About 3,000 specimens were secured on this trip.

Later in the season I spent one day at Golden, one in the suburbs of Denver, one at Palmer Lake, and three at Cimmarron and on Marshall Pass. This last trip was a disappointment owing to the extreme drouth prevail-

ing on the western slope. I intend distributing, during the winter, a list of our duplicates, and invite exchanges; hoping in this manner to increase our collection.

I have received for determination during the season 113 species; these have come from all parts of the State, many of them were weeds, and grasses about which the senders desired information. Often the specimens sent are fragmentary, and these in some cases require hours of time for satisfactory determination.

The letters of inquiry received are numerous. They embrace a wide range of subjects both horticultural and botanical. Attention to this correspondence occupies no inconsiderable portion of my time.

Respectfully submitted,

CHAS. S. CRANDALL,

Botanist and Horticulturist.

Fort Collins, Colcrado,

November 30, 1896.

REPORT

OF THE

CHEMICAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—The force employed on station work is practically one man. The class work leaves no available time during the school year for the professor to devote to station work. The only way that I can devote myself to station work during the year is to place my assistant in charge of the classes.

During the year we have completed the work of our bulletin on Alfalfa, which is now in press. The material for another bulletin, on Alfalfa Hay, is nearly ready and we hope to have this prepared for publication within a few months.

We have undertaken a study of the artesian and river waters of the San Luis Valley. This work is in connection with the survey of the Valley being made by Professor Carpenter, of the Department of Engineering. This is merely a beginning of the work which I have suggested in two of my annual reports as desirable. I am of the opinion now, as I have been, that a study of the chemistry of irrigation would be acceptable and valuable. The work involved in such a study is large in amount, somewhat expensive in its nature, and requires attention.

We have found it impracticable to begin our study of the alkalization of the soil as planned. This work,

however, is simply put off because of the other work and has not been abandoned.

I was sent to Fruita, in June of this year, to examine into the alkalization of the soil which is taking place rapidly in the surrounding country. In this case the alkalization was, I believe, largely due to abundant irrigation, continued for several years, together with inadequate drainage. This case was worthy of study in detail. If systematic observations could have been made during the past few years, four or five, and complete records kept of them the information which they would have afforded would be of great interest to those engaged in the study of the soil. The people there have made some observations but they are mostly confined to the effects produced without due attention to their causes, their rate, or manner of action.

The Professor of Agriculture, W. W. Cooke, and myself were delegated to attend the Fair held at Glenwood Springs to select samples of sugar beets exhibited by contestants in accordance with the terms previously made known by the Association. I subsequently determined the sugar in these samples and furnished the proper persons a statement of the results. The object had in view was to learn, in this way, the probabilities of their being able successfully to cultivate the sugar beet in their soil, and under their climatic conditions, for the production of sugar. We were deterred from visiting the places where the beets had been grown by a severe storm which washed out the roads and bridges and otherwise seriously interfered with our work.

The beets which had not been washed, showed that they had been grown in widely differing soils. Some had been grown in rich, black, valley soils such as are frequently met with in our mountain valleys; others in clayey soils, etc. As it was a competition between the ranchmen of these three counties, Garfield, Eagle, and Pitkin, some had brought large beets, others small ones; and, while each one had taken his sample with the best intention, the lack of uniformity in selecting the samples and the probability that they were not average samples

detract greatly from the results obtained. Another point seemed to be indicated by the growth of the beets, i. e., that the soil had either been very rich or had been heavily manured before being sown to beets. The results of our sugar determinations showed that the percentage of sugar in the beets varied from nine to nearly fifteen per cent. The coëfficient of purity varied greatly, relatively more than the sugar content. The highest coëfficient of purity obtained was 86. The beets showing this coëfficient contained the highest percentage of sugar and were, as a lot, the smallest beets exhibited. We examined fifteen samples, representing two varieties.

When we consider that the competitors in this test had had no previous experience in growing this crop for sugar, the danger of their having chosen an unfavorable soil for their experiment, the probabilities of improper cultivation, and the difficulty in selecting a representative sample, we consider the results as very encouraging.

The Station has, as usual, received some applications for gratuitous work. I try, in such cases, to comply with the requests, especially if the results are of real value and the work is really for the public. As before stated, we have more work on hand than we can get done, and work of this character interferes with us much more than the importance of the work can justify.

Respectfully submitted,

WM. P. HEADDEN,

Chemist.

Fort Collins, Colorado,

December 3, 1896.

REPORT

OF THE

ENTOMOLOGICAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I have the honor to submit the following report from the Entomological Section of the Experiment Station for the year 1896.

The year has not been marked by any extraordinary outbreaks of injurious insects, but heavy losses have been sustained from the attacks of some of our common and ever-present pests. The west is noted for its hordes of grasshoppers, and I have no doubt that they occasion greater loss to the agricultural population of the State each year than any other insect enemy, not excepting the Codling Moth; but the cultivators of the soil have become so accustomed to giving the tithe of all they raise to these marauders that they think little of it and in most cases make no effort to destroy them. It was gratifying to learn that in those localities where the grasshopper disease was most prevalent last year there were comparatively few grasshoppers the past summer. Grasshoppers dying of the disease have been seen in numerous localities of the State the past summer and fall but there has not been the amount of rainfall and cloudy weather necessary to cause the rapid spread of the contagion.

The Leaf-rollers that have been so destructive to the foliage of fruit and box-elder trees in the northern

portion of the State for a number of years past were decidedly less destructive the past summer than in 1895, and they were less destructive in 1895 than in the year preceding. This decrease of injuries from these pests seems to be the direct result of a more extensive use of the arsenical poisons as there are very few parasites preying upon them. I should say, however, in justice to the birds, that they are becoming a very valuable aid in this work, and especially have I noticed flocks of blackbirds alighting in the trees and feeding upon the worms which they pick from the leaf-rolls.

The Flat-headed Borer in apple trees and one of the Cossid Borers in cottonwood trees seem to be increasing in numbers, the former more particularly in the orchards west of the range, and the latter in towns on the eastern slope.

The San Jose Scale (*Aspidiotus perniciosus*) does not occur in the State so far as I am able to determine and those who are purchasing fruit trees from nurseries outside of Colorado should take special precautions to avoid importing this, or other pests, on nursery stock.

The Codling Moth (*Carpocapsa pomonella*) has, at last, worked its way into every part of the State where apples are grown. It is a comparatively rare insect as yet in Delta county, especially in the North Fork districts. The use of arsenical sprays and the practice of bandaging the trees to catch the larvæ should be persistently kept up wherever apples are grown.

The Brown or Clover Mite (*Bryobia pratensis*) continues to be a serious pest on pear or apple trees in the mountain districts. Experiments that I carried on for the destruction of this insect the past season have shown that the eggs, which are laid in enormous numbers about the crotches of the branches and to a less extent all along the branches and twigs, can be easily destroyed during the winter, when the leaves are off, by applying kerosene emulsion in about twice the ordinary strength. The same application will also kill the mites after they hatch, but it is much more economical and easy to kill the eggs before the leaves are out in the spring.

Two serious insect pests, brought to the State from the east, have been reported to the station for the first time the past summer. One of these, the Apple Maggot (*Rhagoletis pomonella*) was taken by myself at Colorado Springs in August. This pest has been introduced without doubt, in infected apples from the east. Superintendent Blinn, of the Arkansas Valley Station, sent me the past summer a number of specimens of the Striped Cucumber Beetle (*Diabrotica vittata*) which he said was becoming quite abundant on melon vines. I also saw a few specimens of the beetle at Canon City last August.

ORCHARD INSPECTION.

On the 16th of last August I started on a brief tour of orchard inspection, going first to Grand Junction and making short stops at Delta, Hotchkiss, Paonia, and Canon City on the return trip. At Grand Junction, I was greatly assisted by B. C. Oyler, County Fruit Inspector, who kindly took me to some of the older orchards in that vicinity. I found a very large portion of the apples wormy. The crop being very light this year, the owners of the orchards thought it hardly worth their while to spray the trees and the worms, that would ordinarily be distributed through a large crop of fruit, were concentrated on the few apples that grew. It is a great mistake not to spray the light crops. By thoroughly treating these the heavy crops that follow would be almost free from infection.

Red Spider (*Tetranichus sp.*) was found quite abundant on plum, apple, willow, and currant. In some cases the currant bushes had dropped nearly all their leaves and, apparently, as the result of the attack of the spiders.

The Brown or Clover Mite (*Bryobia pratensis*) was abundant enough to be decidedly injurious to certain pear, cherry, plum, and apple trees as was evidenced by the bleaching of the foliage.

Pear Leaf-blister, also the work of a small mite (*Prytoptus pyri*) was noticed on a few trees, but not abundant enough to do serious harm.

Cottonwoods about town were bored to a moderate extent by some insect, but they were not suffering nearly so much as they are in several places on the east of the range. Peach and plum foliage gave evidence of having been infested earlier in the summer by plant lice, but were nearly free of these pests at the time of my visit. Peach and apricot trees and grape vines were particularly free from insect injuries.

At Delta, the fruit crop was also light and consequently the injuries of the Codling Moth were showing more than in any previous year; but wormy apples were comparatively scarce, as this insect has not yet become abundant in the orchards of Delta county.

In the vicinity of Delta the conditions of the Red Spider, Clover Mite, and Pear Leaf-blister were almost identical with those at Grand Junction. While visiting the farm of Mr. W. H. Hastings, it was noticed that the foliage of the garden beans was all turning white and many of the plants dying; an examination showed the injury to be due to the attack of Red Spider. Peas and Prickly Lettuce were also in a similar condition only worse. The injury to these plants was due to the presence of enormous numbers of a little black and white Thrip (*Coleothrips 3-fasciata?*) which was in all stages of development upon the leaves.

The Cabbage Worm (*Pieris rapæ*) and the Cabbage Louse (*Aphis brassicæ*) were also found common upon cabbages.

Box-elder trees in the vicinity of Delta were infested by a very small leaf-roller which skeletonized the leaves, folded them, and then spun small white silken cocoons in the leaf-folds.

At Hotchkiss and Paonia, I was greatly assisted in my work by Mr. J. B. McGinty, Fruit Inspector for Delta county, who spent two days with me, taking me into many orchards in the vicinity. Delta county is fortunate in having so enthusiastic and well-informed a person as Mr. McGinty as inspector. This North Fork country may, indeed, be called a fruit-grower's paradise, as far as any trouble from insect pests is concerned. I was

in two orchards where wormy apples were found in small numbers. I was told that this year was the first that a wormy apple had been found in that part of the country. Red Spiders and the Clover Mite were found in small numbers only. The Rose Leaf-hopper (*Typhlocyba rosæ*) was rather abundant on apple trees in one or two orchards, but it could hardly be said that it was in injurious numbers. A single specimen of the Buffalo Tree-hopper (*Ceresa bubalus*) was taken near Paonia from an apple tree and was the only specimen seen.

At Canon City, Howard's Scale (*Aspidiotus howardi*) was found very abundant, and doing considerable injury in the little plum orchard where it was first found, but it seems not to be spreading badly to other orchards. Wormy apples here were extremely abundant. I scarcely ever saw more apples falling as the result of the attack of the Codling Moth. I believe the reason for the large number of wormy apples to be the neglect to attend properly to spraying, which a number of the orchardists think does not pay. Red Spiders and Clover Mites, though common in the orchards about Canon City, seem not to have done serious harm the past season.

Acknowledgments are due to the officers of the Denver and Rio Grande, and the Denver and Gulf railroads for their kindness in furnishing free transportation for the above trip which, otherwise, could not have been made.

All of which is very respectfully submitted,

C. P. GILLETTE,
Entomologist.

Fort Collins, Colorado,
December 7, 1896.

REPORT

OF THE

SECTION OF METEOROLOGY AND IRRIGATION ENGINEERING.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—The work of this Section of the Experiment Station has been conducted on the lines of investigation approved by you. In Meteorology the investigations bearing upon Agriculture and of value in throwing light upon the questions of irrigation have been the special objects of record. This in itself is a work which requires conscientious care in the observer, and unremitting attention from first to last in the careful record of the observations. The accumulation of these exact data is of primary importance in the study of the climate of the Station, and ascertaining the conditions which affect the practice of the agriculturist and the growth of crops. Only with a number of years' observation can safe deductions be drawn. The labor of reduction of the large number of observations is great, but as it is establishing a fund of exact facts which become increasingly valuable each year it is worth its cost. While definite conclusions can be drawn only from a series of years' records, the publications in the annual reports from year to year will give the public access to the data and make them useful to many. From the use made of the figures given

in the reports up to and including 1891, it would seem that they have been useful to many. The data are now extensive enough to warrant the reduction of some lines for the study of special questions.

Observations have been continued on the rise and fall of ground water, and an attempt to trace its connection with the change in water in neighboring canals; amount of loss by seepage, complementary to the investigations reported in Bulletin No. 33; the amount of water used on various crops; the changes in the flow of streams and the relation to the condition of the upper water shed; the amount of evaporation from water surface on lakes and confined areas, and simultaneous record of the wind for study in connection with it. These involve regular and exact observations which have been made principally by Mr. R. E. Trimble, whose care in every detail renders his work worthy of every recognition. Several self-recording instruments have been in use as hitherto. The driving in connection with the collection of these data and more especially in making the weekly rounds of the instruments, has amounted to over 1,600 miles. This has been done almost entirely by Mr. Trimble. An evaporation tank was placed in Lee's Lake during the summer, which, being on the road to other instruments, could be visited with little extra time. This was visited twice per week. On the same raft which served to protect the tank from the waves was arranged a rain gage. The information obtained from this series of observations promises to be more complete than that of past years where the curiosity of the small boy caused the loss of much of the value of the measurements. In this lake used the past summer, there is but one boat, and that a private one, so that the instrument has been under better control.

A nilometer was placed so as to record the rise and fall of ground water in a well near the sub-station near Monte Vista. The records in connection with the data of the flow of the neighboring ditches indicate an early response of the level of the ground water to the change of water in the ditches. The water rises and falls at

that place a number of feet during the year, and has risen some 12 or 13 feet since irrigation was commenced there some years ago. The record will be compared with other data from the Valley collected during the summer season.

There are now sufficient observations to warrant the labor for their reduction. This is if anything more laborious than the collection and recording of the observations themselves, in themselves no inconsiderable task. The only time when this can well be undertaken is during the college scholastic year, as with this Section, the summer season is the time when we can best carry forward the special investigations. But during the school year, with three to six hours with students in lectures and exercises, there is little time or freshness for fruitful original work. In consequence the data are ahead of the reductions and we have a number of subjects which warrant preparation into bulletin form. I hope to be able to arrange the afternoon so as to secure some portion of the day for developing our results.

In the summer a special investigation was begun in the San Luis Valley. This Valley on the Rio Grande in Colorado is the largest of the Rocky Mountain Parks, approximately 100 miles in length and 40 miles in width, with an area of 3,000 square-miles. It has many special questions arising from its peculiar conditions. Having been the bed of a lake, the surface is nearly level, slightly basin shaped, with alternate layers of sand and gravel extending to depths of over 1,000 feet in the axis. The artesian wells have been to some extent discussed in Bulletin No. 16. This investigation was planned to include the questions relating to irrigation and water supply, and especially studying the conditions of sub-irrigation of the Valley whereby the practice is to run water in the ditches without applying it to the surface of the land. The questions of the Valley have also raised international questions with Mexico, the latter country claiming that the irrigation in Colorado has interfered with the rights of her citizens. I visited the Valley in April, making arrangements with some observers for some observations and records, and obtaining the prom-

ise from some of the ditches of records of their discharges. At the close of the college year, I proceeded to the Valley. Mr. Stannard accompanied me, and made the measurements of the streams draining into the Valley, driving in that measurement about 1,000 miles. The key to many of the questions pertaining to the Valley was evidently at the lower end. On my first visit I found what I had suspected, though the maps were all wrong, that there was a short cut from the Conejos or the Pinos streams into the Rio Grande. In August, Dr. Headden and myself crossed from Antonito to Costilla, determining the important point that the water which escapes from the Valley must pass through the deep canon of the Rio Grande, whence the measurement of the stream in the canon includes that which is flowing from the Valley.

A nilometer was placed north of Monte Vista to determine the rise and fall of the ground water. There is an extreme change at that place in the height of the water, and the level responds quickly to the water in the neighboring canals. Mr. Duncan at the sub-station, attended to the instrument.

In measuring the seepage of the Rio Grande, aid was given by the superintendent of that Division, Mr. F. J. Anderson, the Water Commissioner, without whose aid it would have been difficult to find the heads of the ditches which were to be measured.

The investigation indicates greater results than I anticipated in recommending it for a subject of investigation. The Valley being one of magnificent distances, the traveling required exceeded my anticipations. Mr. Stannard, as already mentioned, drove over 1,000 miles, and I drove perhaps 700 in the aggregate. Another summer will be required to work forward to the best results.

Data were obtained from the railroad company and the extensive surveys of the canal companies; by connecting the two lines we were in possession of the levels of a large part of the Valley.

The seepage measurements of the Poudre were taken this fall by Mr. Trimble, aided by Mr. Hawley. The

measurement of the Platte from the mouth of the Poudre to beyond Sterling, not far from the state line, was also made. A storm prevented their going to the state line. Mr. Preston of the State Engineer's office, a graduate from the College in 1892, and Messrs. Hawley and H. A. Calkins, also College graduates, aided. The results show less inflow than last year, the year having been a dry one, less rain having been received and less water applied to the land.

I wish to acknowledge the aid furnished us by numerous persons where we have had occasion to obtain data. Many of them have put themselves to much trouble, have voluntarily accompanied us in some cases for a number of days, and have aided the work in every way in their power, and to the material saving of expense. Were the labor represented in the investigations all to be paid for, the expense would be beyond the sum that has ever been available.

To Frank Trumbull, Esq., of the U. Pac., Denver & Gulf, and Col. S. K. Hooper, of the Denver & Rio Grande we are indebted for the aid or their respective roads.

To P. J. Preston, H. A. Calkins, and R. W. Hawley we are indebted for volunteer service without compensation; the latter two aiding us by two weeks of time accompanied with considerable discomfort in camping in freezing weather. The officers of the Farmers' Ditch Company, in the San Luis Valley, Supt. F. T. Anderson, J. C. Ulrich, Mr. Warburton, of Monte Vista, and many others rendered aid.

Messrs. Lamb, Barnes, Boothroyd, and Mrs. Sherwood have furnished us observations regularly from their special localities; as well as have the superintendents of the various sub-stations. Mr. Horace McClelland has taken continuous interest in the record begun on his place some years ago of the amount of water applied to crops.

Thanking the Committee for their support, this report is Respectfully submitted,

L. G. CARPENTER.

Fort Collins, Colorado,

December 9, 1896.

REPORT

OF THE

SAN LUIS VALLEY EXPERIMENT STATION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I submit herewith the Ninth Annual Report of this Station. On account of no appropriation being made for 1896, only a limited number of experiments have been conducted. The schedule as adopted by the Station Council has been followed as closely as possible.

The general conditions of the past season have not been favorable for good results. During the spring and early summer the indications were all favorable for a good yield of grain and other produce, but during the latter part of the season the water supply was shut off and much damage resulted from drouth.

EXPERIMENTS WITH WHEAT ON SPRING PLOWING.

Two plats of wheat were sown, April 4, to determine whether the stubble in the soil had any effect on the growing crop. Wheat sown on spring plowing is generally a failure in the Valley. Most farmers are of the opinion that the cause is due to the stubble in the soil, keeping it in a lose condition so that it is easily dried out and that on that account grain sowed on spring plowed land suffered for moisture. This theory ought

not to hold good in the case of sub-irrigated land as an abundance of moisture is always furnished to growing plants as long as the ground remains sub-irrigated.

Plat No. 1 was sown on ground which had been plowed deep, the stubble remaining in the soil. After sowing the ground was thoroughly packed by rolling. The yield was fifteen bushels per acre.

Plat No. 2 was sown after the stubble had been burned and the ground plowed shallow. The yield on this plat was the same as on No. 1. During the growing season little or no difference was noticed in the condition of the grain. Both these plats sub-irrigated and compared favorably in results with summer fallowing or fall plowing. In other sections of the State, wheat on spring plowed land generally yielded from three to five bushels less per acre than on either summer fallowing or fall plowing. Wheat sowed on summer fallowing on the station farm yielded 18 bushels per acre.

The difficulty with spring plowing in the Valley seems to be that the stubble interferes with drilling and the seed is not put in the soil deep enough to prevent its being blown out during the spring when high winds prevail. On summer fallowing or fall plowing, the stubble has decayed and does not interfere with deep sowing. Neither of the above plats were injured by the wind in the spring, hence the comparatively fair yield.

A plat of oats was sown, April 25, on ground which had been irrigated and then plowed. The yield was ten bushels per acre. The low yield can be attributed more to the lack of moisture during the latter part of the season than to any other cause.

No results were obtained in the experiments with early potatoes owing to lack of water at the proper time for irrigation. The grass plats sown last spring were also destroyed by drouth. The plats sown last year were all winter-killed with the exception of *Bromus inermis* and timothy. Both these plats came through the winter in good condition and were not destroyed by the drouth.

Young alfalfa was also badly winter-killed. Little difference could be determined in the plats which were sown April 1, May 1, May 15, and June 1 of last year.

Respectfully submitted,

CHAS. A. DUNCAN,

Superintendent.

Monte Vista, Colorado,

November 7, 1896.

REPORT

OF THE

ARKANSAS VALLEY EXPERIMENT STATION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I take pleasure in submitting to you the Ninth Annual Report of the Arkansas Valley Experiment Station.

Owing to the change made by the Board in leasing a portion of the station property, and confining the experiments to eighty acres, a large amount of work was made necessary in platting and leveling and in changing and constructing drives, ditches, and fences. The schedule of experimental work has been closely adhered to in every instance where practicable. While the extra work prevented the carrying out of a part of the plans, the efforts of the season have placed the Station in better condition. The work can now be concentrated, close notes can be kept, and more accurate results, at less expense, can be secured.

IMPROVEMENTS.

The irrigation system for the land leased and that for the station were made separate. The headgate for the eighty acres was moved, thereby drawing the water from the Rocky Ford ditch where it first enters the first

forty acres; thence it is distributed by laterals over that area and conducted to the east forty acres by a newly constructed siphon under the public road which separates the two tracts. The water for the leased land was drawn from one headgate located at the upper corner of the rented field. This avoided dividing water between the station and leased land.

Twelve acres of alfalfa land were broken for experiment plats. The remaining portion of old grain land on the east forty acres was seeded to clover and grasses for field tests and rotation. About a tenth of the area was designed for a permanent pasture. The plats were all planned with convenient ditches and drives and the cross fences were transferred so that the eighty acres used for the Station would be enclosed to itself.

Decided improvements were made in the west field by changing and grading some of the ditches and drives. Bridges and culverts were placed where the laterals crossed the drives; a 14-foot bridge was built over the Rocky Ford ditch; four large dividing gates for distributing water in the laterals were made from lumber obtained in moving and remodeling the old hot house; the old orchard was pruned and a large amount of grading and leveling was done therein and on portions of the fields that were difficult to irrigate; about six acres of orchard and small fruit, for a variety test, were added; the lawn around the station cottage was improved; and trees and ornamental shrubs were set out on the grounds. The building of a shelter for the thermometers and the addition of a standard rain gauge improved the equipment for the weather service. Pig pens were built and some minor improvements made.

CLIMATIC CONDITIONS.

The season has been an exceptionally dry one. The water supply in the river was extremely short, at times hardly sufficient for domestic use. The spring was dry and there were many hard winds that dried out the ground as often as it was irrigated, making it difficult to keep it wet enough for new grass plats to start. The

highest temperature was reached in June, 101 degrees F. The average daily maximums of June, July, and August were 87 degrees, 90 degrees, and 90 degrees respectively. The rainfall was 8.36 inches as follows: March, .23 in., April, .55 in., May, 1.12 in., June, .47 in., July, 2.07 in., August, .47 in., September, 1.85 in., and October, 1.60 in. A late frost and high winds in the spring nearly destroyed the apple crop in this vicinity. The first light frost occurred September 28; the first killing frost, October 12. Where water could be had, the season was favorable to the growth of all crops. Alfalfa seed yielded heavily, corn did well, and melons and cantaloupes were produced abundantly.

INSECTS.

All the unfamiliar species of injurious insects discovered working on crops were sent to the Department of Entomology of the College for determination. The insects injurious to crops are the Codling moth; red spider, on raspberries; tomato worm; grasshoppers; cucumber beetles, on cantaloupes; and cabbage worms and lice on the cabbage plants. Grape-leaf hopper and the larvæ of the eight-spotted alypia were bad on some vineyards. Potato beetles and the potato stem borers did serious work on some of the patches in this vicinity. There were many other insects. With the aid of the sprayer and insecticides the Station suffered little loss from insects.

AGRICULTURAL DIVISION.

Cereals:

Three adjacent plats were prepared for a comparative test of the cost of producing barley, corn, and wheat. The previous year the land had grown a crop of corn and wheat of which each plat contained about an equal area and received the same relative attention. The estimate in these accounts is based on the material used and the labor involved in producing each crop, reckoned at the market value and the regular price of labor—one man, $1.50 per day; a man and team, $2.25 per day. To avoid an uninteresting tabulation of items an epitome of the notes will be given.

Wheat—Four and one-third acres were sown to Amethyst wheat, April 2, with a press drill, at the rate of seventy pounds per acre. The wheat came up well, and made a splendid growth. The ground received four irrigations, and the grain was harvested July 9, with a yield of 33¼ bushels per acre. The expense of the crop was $29.22, or 21½ cents per bushel.

Barley—The plat for the barley contained 5½ acres. It was sown in the same manner and it received the same cultivation and care as did the wheat. The growth was short, which made it difficult to bind. When threshed, it gave a yield of 40 bushels per acre. The expense was $38.05, or 17 cents per bushel.

Corn—The plat of corn grew under less favorable conditions than the wheat and barley. It was planted May 15, but, owing to the uneven condition of the ground, it made a very irregular stand. It received one cultivation and two irrigations. The yield was 25 bushels per acre. The expense, for the 4⅓ acres was $22.25, or 21 cents per bushel.

The following test of corn on alfalfa sod will make a more correct comparison with the wheat and barley.

Corn on alfalfa sod—A four-acre plat was planted, May 12, to corn. The alfalfa had been plowed and cross plowed in the spring. The stand of corn was excellent. It had two cultivations and as many irrigations. When gathered, the yield amounted to 39 bushels per acre. The expense on the plat was $30.50, or 19¼ cents per bushel.

The yield on this plat was estimated by gathering a portion of the corn.

Test of varieties of corn—Four kinds were received from different seed houses; Hickory King, Golden Triumph, Waterloo, Early Dent, and Golden Beauty. Golden beauty is the only one deserving mention. It is of a very beautiful yellow variety. In small plat test, it indicated a yield at the rate of 77 bushels per acre. The other varieties were badly mixed and are not so good as many common varieties in use.

Test of varieties, wheat and other grains—Three small plats were sown to India No. 3 and Royal wheat, and

smooth, Hulless barley. They did well for exhibition purposes. The main experiment on the test of varieties began October 1. Thirty varieties were sown, all of which have made a good start. The results will be reported in the next annual report.

GRASS AND HAY CROPS.

Red Clover—Two attempts were made to start a $2\frac{1}{2}$ acre plat. The first was sown May 12, but dry, hot winds caused a failure. On July 1, the piece was reseeded with 14 pounds of seed per acre. It received four irrigations up to October 1. The plat gives evidence of a good permanent stand.

Crimson Clover—This plat was left until the first of July, when it was irrigated and the weeds plowed under. The ground was leveled and, July 15, $2\frac{3}{4}$ acres were sown to crimson clover, with a press drill, at the rate of 14 pounds per acre. It received the same care as the red clover; yet the stand, over a part of the plat, is very poor. The portion that has a fair stand, gives promise of an interesting test the coming year. As the conditions were unfavorable, the test of crimson clover in the old orchard was omitted this year.

Alfalfa—All the alfalfa hay land (forty-five acres) was handled by the renter. The hay was put up in good shape. The yield was four tons per acre, including three crops.

New Seeding—Two acres adjacent to the crimson clover were sown at the same time, and received the same attention, and made a most excellent stand of alfalfa. The remainder of the old grain land, about four acres, was seeded to alfalfa. The stand is so poor that it will be necessary to reseed in the spring. The alfalfa seed was put in so late that no grain crops were sown with any of it.

Pasture—The three-acre field of *Bromus inermis* has been used as a cow pasture. It had six irrigations. The plat of red clover was used as horse pasture. It required six irrigations to keep it growing.

Seven acres of old grain land were prepared for an addition to the pasture land. It was sown to timothy

and orchard grass, the last of July, but, owing to lack of water, it will require reseeding in the spring. The plat tests of pasture grasses gave no satisfactory results, owing to lack of water at the proper time.

Irrigation—There was no difference in the number of irrigations applied to the new seeding of clover and alfalfa. Another year's observations will offer better opportunity to decide that test. Owing to the varying character of the water supply in the ditch, the measurement of water applied to different crops was almost impossible. A self-registering instrument is needed.

The effects of irrigation applied at morning, noon, and night, were noted on a plat of garden peas. Only two applications were made, and rain intervened so that there was no perceptible difference in the three portions of the plat.

GARDEN DIVISION.

The test of garden vegetables was confined to a few untried varieties. The following test was chosen for exhibition purposes: hemp, broom corn, cotton, okra, ram's-horn bean, yard-long bean, devil's claw, chufas, serpent cucumber, and gourds. A few common vegetables, such as radishes, lettuce, cucumbers, peas, beans, and parsnips were grown.

Hot beds—For starting early plants an ordinary hot bed heated by stable manure was prepared. The bed was forty feet long and divided into three sections, for testing different kinds of covering. Section one was protected by window sash. Section two was covered with common muslin, each square-yard being treated with the following preparation: lime water, 2 oz. and linseed oil, 4 oz., mixed with a gentle heat. When cool, add two well beaten eggs. Apply with a brush and when dry give a second coat. Section three was covered with the plain muslin. Sections two and three had also board coverings that hinged at the upper side. During the day the board covers were hooked up so as to act as wind-breaks and to reflect the heat of the sun. At night, and on cold days, they were lowered to protect the beds. The board covers worked well. The best results were obtained from the glass covered section. The pre-

pared muslin gave better results than the plain muslin, as it seemed to hold heat and moisture better. The main hot-bed growths were cabbage and tomato plants. Some others, as peppers, cauliflowers, celery, and egg plants, were started; but owing to the seed, or to the soil in the hot bed, they were not a success.

Onions—Two varieties, the Gigantic Gibraltar and Red Weathersfield, were tried. The former proved much the better for this soil and climate.

Cabbage—Burpee's World Beater was a failure; Extra Early Cabbage from Scotland, good, but small heads; Christmas Drumhead, nearly a failure; Lupton, good heads of excellent quality; Danish Ballhead, a good late cabbage for this section.

Cauliflower was a failure on account of grasshoppers and worms. Soja beans grew rank but failed to mature seed.

Sweet Corn—Sweet corn is invariably a failure on account of worms. Early Fordhook seemed a desirable corn, but was all destroyed by worms. The Evergreen was badly eaten. New-12-rowed-Early Sugar was a good early variety, but was injured badly by worms. Moore's Early Concord, so far as known, is the only variety to be relied upon here, as it is not badly injured by worms.

Tomatoes—Of ten varieties tested, Ignotum and Fordhook's First were superior. Lemon Blush proved an excellent yellow tomato.

Sweet Potatoes—These are grown in this section with decided success. A small plat was tried on the Station, but the plats were started too late fully to mature the crop.

Peanuts—A small plat of Spanish peanuts was grown with success. They require the same cultivation as the common garden pea. Adjacent to the peanuts was a small plat planted to chufas or earth almonds. They gave an excellent yield, indicating a profitable crop for hog feed.

Celery—Celery was grown fairly well, but the conditions for success have not yet been ascertained. The plants were started in a cold-frame and set out near the bottom of a furrow. They were banked up as they grew.

Melons—Five varieties of water melons were tested. Kleckley's Sweet was the only one that promised to be any improvement over the old reliable Swink melon. The Kleckley's Sweet is a plain, dark green, oblong melon, very solid, and of excellent quality.

Muskmelons—Of five kinds tried, none equaled the little Netted Gem cantaloupe. The Early Hackensack and Banquet are desirable table melons, but are not solid enough for shipping.

Cantaloupes on alfalfa sod—To test the cost of production of cantaloupes on alfalfa sod, a record was kept of the expense of labor for one acre. The ground was broken in March and cross plowed and leveled in April. May 1, the ground was furrowed into rows 6 feet apart. Water was run through the furrows, and, May 4, the seed was planted in hills 6 feet apart. A splendid stand of plants was secured. The plat was cultivated and hoed three times, and irrigated eight times. The yield was 350 marketable crates, (of 40 to 50 cantaloupes each). Expense on the plat was $17.50—a cost of five cents per crate. It was impossible to estimate the cost of marketing these, as, a great part of the time, there was no market for small lots. The cantaloupes were fed to the hogs. The usual cost of marketing cantaloupes, including crates, is from 20 to 30 cents per crate. The average price received by those who shipped car-load lots, by freight, was about $0.50 net.

Sugar beets—One-half acre of alfalfa sod was sown to sugar beets with the view of determining the cost of production. Owing to the lack of proper machinery, and experience in growing beets for profit, the estimate is undoubtedly higher than should be expected. The alfalfa ground was broken in March, cross plowed and leveled. The seed was sown with a press grain drill, (by closing a part of the holes) at the rate of 16 pounds per acre. The rows were 20 inches apart. The moisture in the ground was not sufficient to sprout the seed and, June 18, the plat was flooded. A rather irregular stand of plants was the result. They were hand hoed and cultivated twice, received four irrigations, the last one Sep-

tember 1. Up to the time of this report, they were not dug, but the cost of raising was $14.50. On the average yield of sugar beets, at this Station in previous years, the cost, before digging, would not exceed $2 per ton.

Potatoes—Four early varieties, planted on April 7, were complete failures. They made an excellent growth of vines, and received the best of care, but not a potato set on the vines. This failure was evidently due to some form of blight.

Test of varieties—Eighteen varieties of potatoes were received from the San Luis Valley Experiment Station to test their yielding qualities, and to ascertain a reliable yielding potato in this section of the State. The first plat was planted June 1, on alfalfa sod. It received the best of attention. The area of each kind was small and irregular, and the stand poor in some cases. Instead of estimating the rate of yield per acre, the ratio of the seed planted to the amount of marketable potatoes harvested, is given in the following table as an index to the relative merits of the varieties, as determined by this year's test:—

Variety.	Ratio.
Snow Flake	2.6
Yankee Notion	3.0
Dictator	7.4
Vick's Perfection	3.4
Ohio's Fancy	2.8
Barclay's Prolific	5.9
Early Beauty of Hebron	4.3
Strawberry	4.5
Plymouth Rock	6.2
Negro	8.1
Arizona	3.8
Sterling	0.3
Westminster	4.6
Burbank's Seedling	8.6
Blue Victor	6.5
Empire State	5.0
People's	10.0
Late Ohio	8.3

A duplicate plat of the above varieties, and two acres of Blue Victors and Late Ohios, for a field test, were planted on alfalfa sod, June 20. They made an excellant stand, were cultivated, hilled up, and irrigated twice during the summer; but the vines made a very slow growth until late in the fall, when frost stopped the growths that were forming. When harvested, most of the varieties and a large part of the field tests, did not return the seed planted.

The seasons vary as to the date that potatoes may be planted with prospect of maturity. In 1895, those planted on June 25 were ripe Nov. 1. By continuing these tests for a series of years, the proper dates of planting potatoes may be determined approximately.

HORTICULTURAL DIVISION.

Orchard and small fruits—The ground in the orchard was leveled. The trees stood the shock of a very severe pruning of dead and useless limbs. There was no difference in the effects of the summer and winter pruning. The trees made a good growth in each case. A large number of the varieties bloomed, but a late frost, and the high winds, destroyed all but a few sets on a few trees. No apples worthy of mention, matured. Blight occurred on several trees, but was destroyed as fast as it appeared. A number of orchards in this vicinity show signs of blight. Pears bloomed, but no sets formed.

The uneven condition of the soil in the orchard, would not allow the tests planned for green manuring. Peaches bloomed, but only about two dozen late peaches ripened. Blackberries and dewberries bore fairly well. The vineyard made a good growth of wood but bore very little fruit.

Strawberries—Two attempts to establish a plat of varieties were made. With few exceptions the efforts were unsuccessful, due to the condition of the plants when received, in one case, and in the other, to the intense heat at the time of setting out.

New planting—According to the schedule, the fruit trees and shrubbery, named in the following tables, were

planted. The apple trees were received from the Horticultural Department of the College. The remaining portion was ordered from eastern nurseries and were received, apparently, in good order. They were set out with care, and received the best of attention, and the failure, in many instances, to grow, was due to the long time the orders were en route.

PLUMS.	No. Set.	No. Alive.
Shippers' Pride	3	3
Tatge	3	3
Coe's Golden	3	3
Yellow Egg	3	3
Lombard	3	3
Abundance	3	0
Satsuma	3	3
Burbank	3	1
York State	3	0
Downing Mulberry	2	0
Celestial Fig	2	0
APRICOT.		
Chinese Apricot	2	2
Alexis	1	1
American	3	3
Gold Dust	2	2
Japanese Hubbard	2	2
PEACHES.		
Bokara No. 3	5	1
Crosby	5	0
Sneed	3	0
Elberta	3	3
QUINCE.		
Champion	2	1
Orange	2	2
Meech	2	0
Japan Columbia	2	2
Fuller	2	0

PEARS.	No. Set.	No. Alive.
Japan Golden Russet	3	2
Lincoln Coreless	3	2
Koonce	3	2
Lincoln	3	1

CHERRIES.		
Louis Philippe	2	1
Black Tartarian	2	0
Napoleon Bigarreau	2	0
Dye House	2	0
Lutovka	2	2
Windsor	2	0
Olivet	2	2
Governor Woods	2	1

APPLES.		
Porter	3	3
Coffelt	3	3
Roman Stem	3	3
Hatchers	3	2
Colvert	3	3
Martha Washington	3	1
Benoni	4	4
Fink	3	3
Indian	3	2
Gideon's Best	3	3
Brightwater	3	3
Little Romanite	3	2
Buncombe	3	3
Blue Pearmain	3	3
Gravenstein	3	3
Garden Ball	3	3
White Winter Pearmain	3	3
Western Beauty	3	2
Sweet Bough	3	3
Bailey's Sweet	3	1
Plumb's Cider	3	3
Willow Twig	3	3
Seek-no-further	3	3
Lowell	3	3

	No. Set.	No. Alive.
Gano	3	3
Talman Sweet	3	3
Gideon	3	3
Big Romanite	3	3
Geneton	3	3
Minkler	3	1
Jonathan	3	3
Shockley	3	3
Early Colton	3	2
Alexander	3	3
Early Pennock	3	2
Shannon Pippin	3	3
English Golden Russet	3	3
Lissof Seedling	4	4
Large Striped Pearmain	3	0
Autumn Swaar	3	2
Twenty Ounce	3	0
Painted Lady	3	3
Red Astrachan	3	3
Lord Nelson	3	1
Autumn Strawberry	3	3
Buckingham	3	2
North Carolina Limbertwig	3	2
Gill's Beauty	3	3
St. Lawrence	3	0
Jones's Seedling	3	3
Nickajack	3	3
Red Winter Sweet	3	3
Summer Rose	3	1
White Bellflower	3	3
Early Strawberry	3	3
Beauty of Kent	3	2
Grindstone	3	2
Fall Pippin	3	3
Arkansas Beauty	3	2
Rambo	3	1
American Sumner Pearmain	3	2
Huntsman	3	3
Newton Pippin	3	1

	No. Set.	No. Alive.
Smokehouse	3	1
Vandevere Pippin	3	1
Summer Queen	3	3
Keswick	3	0
Crawford Pippin	3	3
Red Limbertwig	3	2
Domine	3	3
Gideon No. 20	3	3
Winter Greening	3	3
Cullasaga	3	3
Milam	3	3
Langford	3	3
Ohio Nonpareil	3	1

NUT TREES.

Thin Shell Walnut	2	2
Unknown Walnut	2	2
Persian Walnut	6	6
Praeparturien Walnut	4	4
Japan Walnut	2	2
Chaberte Walnut	2	2
Chinquapin Nut	2	2
French Franquette	2	2
Kentish Cob Filbert	2	0
Cosford Thin Shell Filbert	2	0
Butternut	2	1
Shell Bark Hickory	2	0
Papershell Pecan	4	2
Japan Pedigree Chestnut	2	0
Spanish Chestnut	2	1
American Sweet Chestnut	5	0
Soft shell Almond	2	1
Hard shell Almond	2	0
Benabume	2	2
English Filbert	4	4

BLACKBERRIES.

Eldorado	2	0
Erie	6	0
Minnewaski	6	0

	No. Set.	No. Alive.
Taylor	6	0
Snyder	6	0
Kittating	6	1
Stone's Hardy	12	0

GOOSEBERRIES.

Pearl Gooseberry	2	0
Keepsake	2	0
Lancashire Lad	2	1
Chautauqua	2	1
Golden Prolific	2	0
Spineless	4	3
Industry	4	0
Downing	10	1

ORNAMENTAL TREES AND SHRUBS.

American Linden	4	4
Kilmarrick Weeping Willow	2	2
Cut Leaf Weeping Birch	2	2
Snowball	4	4
Lilac	4	4
Hydrangea	2	2
Virginia Creeper	2	2
Honeysuckle	4	2

CURRANTS.

Red Cross Currant	1	0
La Versaillaise	2	2
Cherry Currant	2	2
White Grape Currant	2	2
Champion Black Currant	2	2
Lee's Prolific Currant	2	2
Victoria Currant	2	1
North Star Currant	2	2
Highbush Cranberry	2	0

RASPBERRIES.

Shaffer	4	1
Nemaha	6	6
Ohio	12	0
Miller	2	1

	No. Set.	No. Alive.
Loudon	2	0
Royal Church	6	2
Gregg	6	0
Palmer	12	0
Japan Wineberry	2	1

WIND-BREAK AND HEDGE TESTS

The setting of a wind-break around the orchard was omitted for lack of opportunity. Only two hedge rows were set, one of California Privet, and the other of June roses. These were set along the drive south of the Station cottage. The lawns were improved, enlarged, and kept well mowed and irrigated. A quantity of flower seed was used in starting beds to ornament the grounds around the station cottage.

Respectfully submitted,

PHILO K. BLINN,

Superintendent.

Rocky Ford, Colorado,

November 16, 1896.

REPORT

OF THE

RAINBELT EXPERIMENT STATION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I herewith present the Third Annual Report of the Rainbelt Experiment Station.

When I took charge, April 1, I found the farm in good condition. No crops had been planted, or had any land been prepared for planting. My having to find and buy the varieties of seed named in the schedule caused many of the crops to be planted quite late.

Severe hail storms which did much damage occurred May 30, and August 21. A light hailstorm, June 22, destroyed the cherry crop. Dust storms, May 5 and 6, cut off all small grain which was unprotected. Hot winds in August damaged crops badly. Below is a table which may give some idea of the weather during the growing season.

MONTH	Max. Temp.	Mean Max. Temp.	Min. Temp.	Mean Min. Temp.	Mean Temp.	Max. Daily Range	Mean Relative Humidity	Precipitation	No. of Rainy Days	Per Cent. of Cloudy Days	Prevailing Wind
April	85.4	69.8	10.5	35.5	52.0	52.8	60.8	3.4	4	32.0	S. E.
May	90.0	76.7	33.6	48.1	62.1	44.6	48.9	2.28	6	53.4	S. E.
June	98.0	87.4	42.4	54.1	70.8	47.8	53.8	3.03	8	41.0	S. E.
July	95.4	88.3	55.0	60.3	74.3	35.4	54.8	2.27	7	36.5	S. E.
August	101.3	88.8	41.0	59.9	74.3	44.6	57.3	3.07	2	36.0	S. E.
September	94.6	76.1	35.0	48.4	62.2	46.1	71.5	.84	3	57.0	S. E.
Total precipitation								14.90			

All hoed crops, and trees, were cultivated after each rain, and as often between rains as was necessary to insure the presence of a soil mulch. Culture ceased about the middle of July.

The heavy rain of May 30 packed the soil very hard in the lister furrows. A special harrow was made which was used to stir the crust thus formed in the furrows, and all listed crops were given one cultivation with this tool.

FARM CROPS.

Corn—Four acres each of Queen of the Field, White Australian, Colorado White, and White Kansas King were planted. Half of each variety was listed, and half planted across land stirred different depths. All were damaged so much by the hot winds in August that very little grain was produced. The effect of the different ways of preparing the land could not be seen. One-fourth of the White Australian was thinned to four feet apart in the row. This section grew to twice the height attained by the unthinned section, and did not succumb to the hot winds as soon as the thick corn.

May 26, one row fourteen rods long of each of the following varieties of corn was planted: Eclipse, Great Long White Flint, Will's Gehu 70-day, Improved Leaming, Pride of the North, Sanford's Early, New England Flint, Early Prairie King, Early Butler, Early Thompson, Queen of the Field, White Australian, White Kansas King, and Colorado White. A few ears were produced by Pride of the North. Every hill of Will's Gehu bore ears. The other varieties produced no seed.

SORGHUMS.

Two acres each of White Milo Maize, Egyptian Rice corn, and Red Kaffir corn, and one-half acre of White Kaffir corn were planted with a lister. None matured seed. The difference in growth on the various types of soil was visible throughout the season. There was ten times as much feed per acre on the heavy soil as on the light types of soil. The difference in moisture supply will not account for all the difference in growth, as heavy

soil in high places produced much better than the light soil beside it. Nearly all the land planted to the non-saccharine sorghums was of the lighter type, which accounts for the small yield. The different varieties produced as follows:—

White Milo maize, 2,200 pounds dry fodder per acre.
Egyptian Rice corn, 1,800 pounds dry fodder per acre.
Red Kaffir corn, 2,200 pounds dry fodder per acre.
White Kaffir corn, 2,000 pounds dry fodder per acre.

Two acres of Early Amber cane were planted May 28 upon plowed ground with a planter drill. It matured seed and was cut September 8, making a light yield of fodder.

May 26, rows 100 feet long were planted to varieties of sorghums. Early Amber cane, Kansas Orange cane, Fodder cane, Jerusalem corn, Large African millet, Brown Durra, Yellow Milo maize, White Kaffir corn, Red Kaffir corn, and Black Rice corn were tested. The seed was donated by Barteldes & Co., of Lawrence, Kansas. All except Black Rice corn gave a perfect stand. The Jerusalem corn and Brown Durra ripened seed, and were headed September 4. The Jerusalem corn yielded 1,416 pounds and the Brown Durra 2,950 pounds of dry heads per acre. Early Amber cane was ripe September 15. Yellow Milo maize and Black Rice corn were ripe September 20. The other varieties ripened but very little seed. No estimate was made of the yield of fodder, as the hail August 21 cut nearly all the fodder off, and the early varieties did not renew their foliage. But it was easily seen that the latter varieties produced the most fodder.

Broom corn—Two acres of each Missouri Evergreen, Tennessee Evergreen, and California Golden were planted. All were planted with a planter drill except one acre of California Golden, which was listed. The hot winds damaged it badly. The lay of the land and the kind of soil and subsoil seemed to influence the yield more than variety and difference in the preparation of the soil. In basins which caught the run-off water the plants flourished. Also on heavy, clay land the brush was worth cutting.

SMALL GRAIN.

Barley—One acre of Highland Chief, one-half acre of Imperial Black Hulless, one-fourth acre of Mansury, and one-fourth acre of White Barley were sown April 20 on light hill soil. The dry weather in May destroyed nearly all of it. A part of the Imperial Black Hulless and Mansury was cut for hay.

Oats—One acre of Excelsior oats was sown April 7 and plowed in. April 21, one acre of Black Russian oats was sown. All were destroyed by the dust storms, May 5 and 6.

Wheat—One acre of Defiance wheat was sown April 7. A half acre of the same variety was sown April 21. Also one-half acre of Blount's No. 16 was sown April 21. All varieties were broadcasted and plowed in. The sandstorms damaged some portions of the plats so that only a small part of each showed a good stand at cutting time. All were cut for hay. It was noted that the wheat ripened very unevenly. Some spots showed wheat dead ripe while in other places, on the same plat, the wheat was still in the milk stage.

Cultivating small grain—Rows of several varieties of oats and rye were planted three and one-half feet apart and cultivated carefully. By this method, good samples of seed grew beside the field plats where the latter failed to make straw.

Millet—One-fourth acre each of Common, German, and Hungarian millet was sown June 12 on one of the plats where oats had been destroyed by the sandstorms. All gave a good stand, but were badly damaged by drought and hot winds. The crop revived after the rain of August 21, and a light mowing of hay was taken from the plats of German and Hungarian millet. The German millet gave the best yield.

Hog millet, or Hirse—A small plat was sown to hog millet, June 12. It was cut August 12, making about 1,600 pounds of hay per acre. The land upon which the hirse grew was plowed April 6 and planted to Soja beans. The beans were destroyed by hail May 30. The plat was

carefully cultivated from the time it was plowed until the Hog millet was sown. Sections of soil and subsoil are essentially the same on all the millet plats.

HORTICULTURE.

All the trees have made a reasonably good growth. Nearly all the currants and grape vines are dead. Gooseberries and raspberries are still holding their own. The Rocky Mountain cherry bushes were loaded with fruit, which the hail destroyed.

Garden—A small plat was planted to garden truck April 30. The onions and radishes were eaten by insects, but the peas, beans, and lettuce did well.

Melons, pumpkins, and squashes were planted June 12. A good supply of squashes was grown. Nothing else matured.

Canada peas—One-fourth acre of Golden vine pea was planted in rows by sowing in every third furrow. The first peas which set were picked the last of June when the vines began drying up. Rain revived the vines, and they bore a light crop of dry peas.

Soja beans—A plat was planted with seed furnished by Prof. Georgeson, of the Kansas State Agricultural College. The hail completely destroyed them, while Mexican beans and Canada Field peas revived and produced seed.

Cow peas and beans—June 20, one-fourth acre each of Mexican beans, Navy beans, and Black-eyed cow peas was planted. From the cow peas, fifty pounds of dry pods were picked. The others were full of green pods when frost came, but ripened very few seeds.

Potatoes—One and one-half acres were planted to Late Ohio, Vick's Perfection, Mammoth Pearl, and Mammoth Prolific. A small section of the plat was planted April 30. The remainder of the plat was planted May 22. Beetles attacked the vines as soon as they appeared. First, the Colorado beetle came. Its ravages were checked first by picking the mature beetles and crushing all eggs and larvæ found, and later by a friendly bug which fed upon the larvæ. The blister beetles (Meloidæ)

came in hordes about June 20. The vines were treated with Hammond's Slug Shot, Paris green and lime, and with Paris green and water repeatedly with no permanent results. The beetles would leave when the remedies were applied, but the vines would soon be again covered with them. Finally, in sheer desperation, we went over the field systematically every few days and killed the beetles with staves. In this way some of the vines were saved alive until the rain and hailstorm of August 21. After this no beetles were seen in the field, and the vines that were yet alive renewed their foliage and produced some tubers.

SUBSOILING.

In April, five acres were subsoiled twelve inches deep. Corn, broom corn, and Early Amber cane were planted across this plat and across two other plats of ground plowed four and eight inches deep respectively. No difference in the growth of the crops on the different plats could be seen.

ROOT INVESTIGATION.

Work in this line was confined to a study of the roots of Indian corn in different soils, and at various stages of development. Corn was planted eight feet apart on well-prepared ground and thinned to one stalk in a hill. Stalks were dug out and their roots traced 30, 45, and 60 days from the time of planting. The soil was a mulatto sandy soil about eight inches deep underlaid by a very fine-grained ashy-gray subsoil. In this soil, we found that the earlier whorls of roots grew down at an angle of about forty degrees and later whorls penetrated at greater angles until the sixth, and all whorls later than it grew almost straight down. Thirty days after planting, roots were traced two and one-half feet deep, and three feet from the plant. Later some roots were traced five feet deep and as far aside.

The earlier roots were small in all cases. The size gradually increased as whorls were added until the roots of the fifth whorl, where the roots grew to the maximum size. The upper whorls were sharply defined, but the

lower whorls were often so intimately blended that it required careful dissection to determine to which whorl a root belonged.

Some writers have claimed that the later whorls of roots which penetrate the soil almost perpendicularly are used to supply the plant with water, and differ in structure from other roots so as to be especially adapted to that work. A few specimens of roots from different whorls which I have hastily examined in cross section show essentially the same structure. A core of compact cells in the centre of the root is surrounded by a ring of ducts. These are surrounded by compact tissue and that by the epidermis. There is no doubt that the later roots *do* supply more water than the earlier ones. Being larger, the number of ducts is usually twice as many as in the first roots. The ducts appear to be the same size in all the roots. Specimens have been preserved for more careful examination.

When the corn was at its best, the roots of plants growing upon different types of soil were traced. It was found than in a black adobe soil, the roots grew near the surface, mostly in the upper foot of soil. In this soil, the roots did not grow to great length, but turned and twisted about very much. The one which grew deepest, was traced to thirty inches below the surface.

In a deep, heavy soil, containing much clay, the earlier roots were below the depth to which the cultivator reaches at six inches from the plant. All grew down at a moderately sharp angle, but did not grow so far from the plant as they did in the ashy or "gopher clay" subsoil. Very few were traced deeper than three feet, while the greater part of them fed in the upper two feet of soil.

SOIL EXAMINATION.

So many inequalities in the growth of crops were noticed, even on the same level and where all visible conditions were the same, that we decided to examine below the surface for causes. The preliminary work was done by digging holes three feet deep every five

rods each way all over the cultivated land. The holes were numbered and a map drawn showing the location of each one. The different types of soil were noted, and samples of each, as well as samples of soil varying from the types, were taken and preserved. While digging, the thickness of each stratum of soil, the variations from types, the presence of lime or volcanic dust, and all other peculiarities seen were noted. A section across the field shows some peculiar changes. In one place, there is an irregular piece of ground a few square rods in extent which shows a stiff, black soil on the surface. In the thickest part, this soil is three feet thick. It varies from that thickness to a mere feather edge, the edge being covered several inches deep by the surrounding mulatto soil. Both the black and the mulatto soils are underlaid by the same kind of subsoil.

It is hoped that before another crop is planted a part of the field may be examined more in detail so as to enable us to map the strata in sections showing their undulations.

A microscopic examination of the soils show that nearly all the grains are angular instead of being rounded as in many transported soils. In many places flakes having the appearance of lime were found in abundance. Some of these fragments resemble volcanic dust, deposits of which are found in a few places in this country.

CAPILLARY RISE OF WATER IN SOILS.

In making this test, the method used by Dr. Hilgard and Prof Loughridge and described in the "Report of the Work of the Agricultural Experiment Stations of the University of California for the years 1892-'93 and part of 1894," was employed. Three columns of soil were built up. One was the common mulatto sandy soil, another black adobe, and the third was "gopher clay." Samples of the "gopher clay" contain particles so fine that they appear as mere specks when examined with a microscope which magnifies 345 diameters. The following table shows the rate of the rise of water in tubes filled with the three different types of soil.

TIME FROM STARTING	ADOBE	MULATTO	GOPHER CLAY
2 hours	5 inches	8 inches	6 inches
14 hours	12 inches	17 inches	17½ inches
24 hours	14¼ inches	20½ inches	21½ inches
50 hours	18¼ inches	26¼ inches	27¾ inches
74 hours	20½ inches	27⅝ inches	32⅛ inches
6 days	23⅜ inches	31¼ inches	37⅝ inches
15 days	28½ inches	34⅞ inches	45 inches
30 days	32 inches	38 inches	51½ inches
60 days	36 inches	41½ inches	58½ inches
90 days	37¼ inches	43 inches	63 inches

The tubes are still standing, and the water is still rising in all. I hope to repeat this experiment using more types of soil.

WIND-BREAKS.

May 3, all of the small grain was up so that it could be seen a long distance. But May 5 and 6 a strong southeast wind blew so much sand across the field that all was cut off except what was protected. South of the east end of the plats was a field of cornstalks still standing. The grain north of these was completely protected, although the grain field was twenty rods wide. South of the west end of the small grain field was newly-plowed land. The grain north of this was not cut off. The grain between the two protected parts was either cut off entirely or left hanging by threads.

All the small grain in this neighborhood suffered in the same way from this storm. We found that furrows run east and west across a wheat field would lessen the damage done by the rolling sand.

In cutting fodder this year, I have left a few rows standing every five rods in order to protect the land from the ravages of the wind, and also to catch snow in winter.

ADDITIONS AND IMPROVEMENTS.

The buildings have been repainted this year. Material is now on hand for the construction of an imple-

ment shed and a cellar. During the summer, a sod wall wind-break twelve rods long and four feet high was built for experimental purposes, but was not used because the physical apparatus necessary for performing the experiment was not received in time. We hope to extend the wall and use it next year to determine the influence of wind-breaks upon evaporation. Fifty dollars' worth of tools and apparatus has been bought for use in studying the soil and conducting evaporation experiments. A combined lister and drill was added to the farm tools.

Respectfully submitted,

J. E. PAYNE,

Superintendent.

Cheyenne Wells, Colorado,

November 4, 1896.

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TENTH ANNUAL REPORT OF THE AGRICULTURAL EXPERIMENT STATION OF COLORADO FOR THE YEAR 1897

HOME STATION
FORT COLLINS, COLORADO
DECEMBER 8, 1897

PRESS OF
THE SMITH-BROOKS COMPANY, STATE PRINTERS
DENVER, COLORADO

LETTER OF TRANSMITTAL.

HON. ALVA ADAMS,
Governor of Colorado.

Sir:—Agreeably to law, I herewith submit the Tenth Annual Report of The Agricultural Experiment Station of Colorado.

Since the establishment of the Station its principal lines of work have been as follows: Chemistry; field experiments; irrigation; horticulture; botany; entomology; and meteorology.

Within the year, just closed, scientific irrigation investigations have been carried on in the San Luis valley; experiments connected with the growing of sugar beets, in different parts of the State, have received careful attention from the Agriculturist and the Chemist; and stock feeding experiments have been prosecuted with results of value to what is becoming an important industry in many sections of Colorado.

The bulletin literature issued by the Station is of practical value to every one in any way interested in farming. The demand for bulletins is usually in excess of the supply, although an edition of 6,000 or 7,000 of each is printed.

In their appropriate place, in the report, will be found the financial statement, of the Secretary of The State Board of Agriculture, showing the handling of the Experiment Station Fund; the reports of the Section officers composing the Station Council; and the Superintendents' accounts of the year's work at the Arkansas Valley sub-station, at Rocky Ford, and the Rainbelt sub-station at Cheyenne Wells.

Respectfully submitted,

ALSTON ELLIS,
Director.

FORT COLLINS, COLORADO,
DECEMBER 31, 1897.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

BOARD OF CONTROL:

THE STATE BOARD OF AGRICULTURE.

EXECUTIVE COMMITTEE IN CHARGE:

A. L. Kellogg, *Chairman*, Alston Ellis, John J. Ryan,
P. F. Sharp, B. F. Rockafellow.

STATION COUNCIL.

Alston Ellis, A. M., Ph. D., LL. D........President and Director
W. W. Cooke, B. S., M. A........................Agriculturist
C. S. Crandall, M. S................Horticulturist and Botanist
W. P. Headden, A. M., Ph. D........................Chemist
L. G. Carpenter, M. S......Meteorologist and Irrigation Engineer
C. P. Gillette, M. S..............................Entomologist
J. E. DuBois......................................Secretary
F. H. Thompson, B. S., Stenographer.

ASSISTANTS.

F. L. Watrous.....................................Agriculturist
J. H. Cowen, B. S..............................Horticulturist
Louis A. Test, B. M. E., A. C........................Chemist
R. E. Trimble, B. S.......Meteorologist and Irrigation Engineer
E. D. Ball, B. S.................................Entomologist

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SUB-STATIONS.

W. F. Crowley................................Superintendent
Arkansas Valley Experiment Station, Rocky Ford, Colorado.
J. E. Payne, M. S............................Superintendent
Rainbelt Experiment Station, Cheyenne Wells, Colorado.

STATION EMPLOYES, 1897-1898.

HEREWITH ARE GIVEN THE NAMES OF ALL PERSONS REGULARLY CONNECTED WITH STATION WORK, THE POSITIONS FILLED, AND THE SALARIES RECEIVED.

Home Station— Names and Positions.	Annual Salaries from Station Fund.	
Alston Ellis, Director	$ 900.00	
W. W. Cooke, Agriculturist	500.00	
C. S. Crandall, Horticulturist	500.00	
Wm. P. Headden, Chemist	500.00	
C. P. Gillette, Entomologist	500.00	
L. G. Carpenter, Meteorologist and Irrigation Engineer	500.00	
J. E. DuBois, Secretary Executive Committee and Station Council	500.00	
ASSISTANTS.		
Frank L. Watrous, Agriculture	$ 1,000.00	
Jacob H. Cowen, Horticulture	1,000.00	
Louis A. Test, Chemistry	1,000.00	
Elmer D. Ball, Entomology	1,000.00	
Robert E. Trimble, Meteorology	900.00	
Fred Alford, Chemistry	540.00	
John E. Kiteley, Chemistry	540.00	
Sub-Station Superintendents—		
W. Frank Crowley, Rocky Ford	800.00	
J. E. Payne, Cheyenne Wells	800.00	—$11,480.00

The yearly expense for labor is about $1,800.

THE STATE EXPERIMENT STATION.

SECRETARY'S FINANCIAL STATEMENT OF THE EXPERIMENT STATION FUND FOR THE FISCAL YEAR ENDING JUNE 30, 1897.

Receipts—	United States.	College.	Total.
United States Treasurer	$15,000.00	$.........	$15,000.00
Farm Products	....	2,358.76	2,358.76
Total	$15,000.00	$ 2,358.76	$17,358.76
Expenditures—	United States.	College.	Total.
Salaries	$ 9,399.40	$.........	$ 9,399.40
Labor	1,636.76	....	1,636.76
Publications	838.00	419.87	1,257.87
Stationery	203.29	....	203.29
Freight and express	79.56	....	79.56
Heat, light, and water	4.00	....	4.00
Chemical supplies	130.65	....	130.65
Seeds, plants, and sundry supplies	485.11	....	485.11
Fertilizers	85.00	....	85.00
Feeding stuffs	631.17	....	631.17
Library	7.18	....	7.18
Tools and implements	62.48	....	62.48
Furniture and fixtures	25.90	....	25.90
Scientific apparatus	136.11	....	136.11
Live-stock	702.86	....	702.86
Traveling expenses	498.03	....	498.03
Contingent expenses	10.00	....	10.00
Buildings and repairs	64.50	....	64.50
Cash on hand	....	1,938.89	....
Total	$15,000.00	$ 2,358.76	$17,358.76

EXPERIMENT STATION INVENTORIES.

NOVEMBER 30, 1897.

AGRICULTURAL SECTION, FORT COLLINS—		
Farm Implements	$ 449.50	
Office Fixtures	135.00	
		$ 584.50
HORTICULTURAL SECTION, FORT COLLINS—		
Instruments	$ 173.14	
Supplies	427.30	
		$ 600.44
SECTION OF IRRIGATION AND METEOROLOGY, FORT COLLINS—		
Meteorological Instruments	$ 391.40	
Irrigation Apparatus	386.78	
Hydraulic Apparatus	150.70	
Stationery, Books, Maps, etc	118.14	
		$ 1,047.02
ENTOMOLOGICAL SECTION, FORT COLLINS—		
Laboratory Supplies	$ 86.70	
Entomological Supplies	53.30	
Insecticides and Apparatus	115.15	
Apiary Supplies	124.70	
Microscopical Apparatus in Charge	335.00	
Apiary Building and Supplies	30.45	
		$ 745.30
Total for Home Station		$ 2,977.26
ARKANSAS VALLEY STATION, ROCKY FORD—		
Two Hundred (200) Acres of Land	$ 9,800.00	
Water-Rights and Apparatus	1,858.00	
Buildings and Fencing	2,364.90	
Live-stock	288.00	
Farm Implements	584.40	
Farm Products of Hand	700.43	
		$15,595.73

SAN LUIS VALLEY STATION, MONTE VISTA—		
One Hundred and Sixty (160) Acres of Land	$ 2,110.00	
Twenty (20) Inches of Water in Rio Grande Canal.	300.00	
Buildings, Fencings, and Well	1,497.00	
Horses, Wagon, and Harness	175.00	
Farm Implements, etc	71.55	
		$ 4,153.55
DIVIDE STATION, MONUMENT—		
Forty (40) Acres of Land	$ 200.00	
Buildings	700.00	
		$ 900.00
RAINBELT STATION, CHEYENNE WELLS—		
One Hundred and Sixty (160) Acres of Land	$ 220.00	
House, Barn, Fencing, etc	1,415.00	
Live-stock, and Implements	284.75	
Farm Products and Supplies on Hand	97.25	
		$ 2,017.00
Total of Sub-Station Property		$22,666.28

EXTRACTS FROM THE "HATCH ACT."

Extracts from the act of Congress, known as the "Hatch Act," approved March 2, 1887, for the establishment of Agricultural Experiment Stations in connection with Colleges established in the several States under the provisions of the Congressional Act, approved July 2, 1862, and known as the *first* "Morrill Bill."

Section 1. * * * That in order to aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture, and to promote scientific investigation and experiment respecting the principles and applications of agricultural science, there shall be established under direction of the college or colleges or agricultural department of colleges in each State or Territory established, or which may hereafter be established, in accordance with the provisions of an act approved July 2, 1862, entitled "An Act Donating Public Lands to the Several States and Territories which may Provide Colleges for the Benefit of Agriculture and the Mechanic Arts," or any of the supplements to said act, a department to be known and designated as an "Agricultural Experiment Station." * * *

Section 2. That it shall be the object and duty of said experiment stations to conduct original researches or verify experiments on the physiology of plants and animals; the diseases to which they are severally subject, with the remedies for the same; the chemical composition of useful plants at their different stages of growth; the comparative advantages of rotative cropping as pursued under a varying series of crops; the capacity of new plants or trees for acclimation; the analysis of soils and waters; the chemical composition of manures, natural or artificial, with experiments designed to test their comparative effects on crops of different kinds; the adaptation and value of grasses and forage plants; the composition and digestibility of the different kinds of

food for domestic animals; the scientific and economic questions involved in the production of butter and cheese; and such other researches or experiments bearing directly on the agricultural industry of the United States as may in each case be deemed advisable, having due regard to the varying conditions and needs of the respective States or Territories.

Section 3. * * * It shall be the duty of each of said stations, annually, on or before the first day of February, to make to the Governor of the State or Territory in which it is located a full and detailed report of its operations, including a statement of receipts and expenditures. * * *

Section 4. That bulletins or reports of progress shall be published at said stations at least once in three months, one copy of which shall be sent to each newspaper in the States or Territories in which they are respectively located, and to such individuals actually engaged in farming as may request the same, and as far as the means of the station will permit. Such bulletins or reports and the annual reports of said stations shall be transmitted in the mails of the United States free of charge for postage, under such regulations as the Postmaster General may from time to time prescribe.

Section 5. That for the purpose of paying the necessary expenses of conducting investigations and experiments and printing and distributing the results as hereinbefore described, the sum of $15,000 per annum is hereby appropriated to each State, to be specially provided for by Congress in the appropriations from year to year, and to each Territory entitled under the provisions of Section 8 of this act, out of any money in the treasury proceeding from the sales of public lands, to be paid in equally quarterly payments, on the first day of January, April, July and October in each year, to the Treasurer or other officer duly appointed by the governing boards of said colleges to receive the same, the first payment to be made on the first day of October, 1887; *provided, however*, that out of the first annual appropriation so received by any station an amount not exceeding one-fifth may be expended in the erection, enlargement or repair of a building or buildings necessary for carrying on the work of such station, and thereafter an amount not exceeding five per centum of such annual appropriation may be so expended.

* * * * * * *

Section 7. That nothing in this act shall be construed to impair or modify the legal relation existing between any of said colleges and the government of the States or Territories in which they are respectively located.

Section 8. * * * And in case any State shall have established under the provisions of said act of July 2 aforesaid an agricultural department or experiment station in connection with any university, college or institution not distinctively an agricultural college or school, and such State shall have established or shall hereafter establish a separate agricultural college or school, which shall have connected therewith an experimental farm or station, the Legislature of such State may apply, in whole or in part, the appropriation by this act made to such separate agricultural college or school, and no Legislature shall by contract, express or implied, disable itself from so doing.

Section 9. That the grants of money authorized by this act are made subject to the legislative assent of the several States and Territories to the purposes of said grant; *provided*, that payments of such installments of the appropriation herein made as shall become due to any State before the adjournment of the regular session of its Legislature meeting next after the passage of this act shall be made upon the assent of the Governor thereof, duly certified to the Secretary of the Treasury.

Section 10. Nothing in this act shall be held or construed as binding the United States to continue any payments from the treasury to any or all the States or institutions mentioned in this act, but Congress may at any time amend, suspend or repeal any or all the provisions of this act.

CIRCULAR FROM OFFICE OF EXPERIMENT STATIONS.

Extracts from a circular issued from the office of Experiment Stations under authority of the United States Department of Agriculture.

This Department holds that the expenditure of funds appropriated in accordance with the provisions of the act of Congress of March 2, 1887, for the maintenance of permanent sub-stations, is contrary to the spirit and intent of said act. The act provides for an experiment station in each State and Territory, which, except in cases specified in the act, is to be a department of the college established under the act of Congress of July 2, 1862. The objects of the stations as defined in the first mentioned act are evidently of such a character as to necessitate the services of scientific and expert workers. Most of the lines of investigation named in the act are general rather than local, and involve scientific equipment and work. The sum of $15,000 which is annually appropriated by Congress under this act for each station is only sufficient to carry out a limited number of investigations of the kinds contemplated by the act.

Thorough work in a few lines has been found much more effective and productive of more useful results than small investigations in numerous lines. When we consider the nature of the investigations, the amount of money provided for the work of each station, and the fact that the act expressly provides for only a single station in connection with each college, it becomes very clear that expenditures such as are necessary to effectively maintain permanent sub-stations ought not to be made from the funds granted by Congress to the States and Territories for experiment stations. The sums of money which can be expended for permanent improvements under the act of Congress aforesaid are so small that it is clear they were not intended to meet the needs of more than one station in each State and Territory.

When the legislature of a State or Territory has given its assent to the provisions of the act of Congress of March 2, 1887,

and has designated the institution which shall receive the benefits of said act, it would seem to have exhausted its powers in the matter. The responsibility for the maintenance of an experiment station under said act devolves upon the governing board of the institution thus designated. If the legislature of the State or Territory sees fit to provide funds for the equipment and maintenance of other experiment stations and to put them under the control of the same governing board, well and good, but this does not in any way diminish the responsibility of the board to administer the funds granted by Congress in accordance with the provisions of said act.

The performance of ordinary farm operations by an experiment station does not constitute experimental work. Operations of this character by an experiment station should be confined to such as are a necessary part of experimental inquiries. Carrying on a farm for profit or as a model farm, or to secure funds which may afterwards be devoted to the erection of buildings for experiment station purposes, to the further development of experimental investigations, or to any other purpose, however laudable and desirable, is not contemplated by the law as a part of the functions of an agricultural experiment station established under the act of Congress of March 2, 1887. Section 5 of that act plainly limits the expenditure of funds appropriated in accordance with said act to "the necessary expenses of conducting investigations and experiments and printing and distributing the results."

ANNUAL REPORT SECRETARY OF AGRICULTURE.

Extracts from the annual report of Hon. James Wilson, Secretary of Agriculture, for the year 1897.

OFFICE OF EXPERIMENT STATIONS.

The agricultural experiment stations, now in operation in every State and Territory except Alaska, continue to carry on a large amount of scientific and practical work giving results of great value to American agriculture. They enjoy more largely than ever the support and confidence of farmers and horticulturists. A number of the States have liberally supplemented the funds appropriated by Congress for the maintenance of the experiment stations. During the past year the revenues of the stations aggregated more than a million dollars, of which $720,000 was received under the act of Congress of March 2, 1887.

No country equals the United States in the liberality with which it maintains institutions for agricultural research and in the thoroughness with which the results of their work are disseminated among the people in whose interests they were established. So great has been the success of our stations and so urgent have been the demands for the information which they are able to give, that the calls upon station officers for the preparation of popular bulletins and the delivery of addresses at farmers' meetings have in many cases been more than it was possible for them to meet without endangering the success of the original investigations which it was their first business to conduct.

While the farmers of the country may well congratulate themselves on having such numerous and important agencies for the discovery of new truths and the dissemination of useful information regarding the practice of their art, they should not relax their efforts to aid the stations in advancing the efficiency of their work and securing the greatest benefits to agriculture which can be obtained with the resources at their command. Many of our experiment stations are doing all that could reasonably be ex-

pected of them with the means and facilities at their command, but in some cases, as the investigations made by this Department have shown, the stations are hindered in their work by causes which might easily be removed. Some of the difficulties which the stations encounter grow out of the fact that the people are not sufficiently alive to their interests in this matter to insist that the station work shall be performed in accordance with a consistent and permanent policy. It is obvious that thorough agricultural investigations can not be made if the plans and personnel of the station are being constantly shifted. This fundamental fact has been too frequently overlooked by appointing officers and boards of control. Fitness and ability to carry on successful investigations should be the fundamental qualifications for station officers, and when competent men are once obtained, they should be made secure in their positions and supported in their efforts to plan and carry out thorough experiments.

The funds appropriated by Congress for the experiment stations are intended solely for the carrying on of agricultural investigations and the publication of the results. The stations are by law made departments of the land-grant colleges, but it was not intended that any part of the station funds should be used for the payment of the salaries of the teaching force or for any other general college purposes, nor that the expenses attendant upon the management of farms or dairies for other than experimental purposes should devolve upon the stations. It is evident that in some cases the college has encroached upon the station, and there is still need of greater care in this matter. It is the duty of all institutions receiving the benefits of the land-grant and Morrill acts to make ample provision for the maintenance of the courses in agriculture without in any way diminishing or diverting the funds which should be devoted to the experiment stations.

The stations should confine their operations to such lands and herds as are actually required for the carrying on of experimental inquiries in a few lines determined upon as best adapted to promote the interests of agriculture in their respective States.

OUTLINES OF STATION WORK FOR 1897.

AGRICULTURAL SECTION.

It is desired to continue the present experiment on the raising of early lambs for market; and to continue the present tests of dairy feeds in the barn and on pasture.

The pig feeding experiment with the present series of nine sets of animals will close about May 1, and it is desired to use all the animals through the summer in a test of the pasture value of alfalfa, with and without grain.

FARM CROPS.

I. Tests of varieties of wheat, oats, barley, and corn.
II. Tests of different times of irrigation on corn.
III. Test of the disc plow on sugar beets.
IV. Test of top dressing for alfalfa.
V. Pasture grasses for sheep feed.
VI. Forage crops for alkali ground.
VII. Effect of missing hills on the growth of corn.
VIII. Colorado seed corn compared with that from other states.

DIGESTIBILITY OF ALFALFA.

It is desired to make this the principal work of the summer. To make the tests a success as outlined in the communication sent to the Committee last December, will require a great deal of work and some expense. It will require the gathering of samples on both a small and a

large scale all through the summer and the feeding of these samples to both steers and sheep. This is work, however, that can be done by the regular force now on the farm, without hiring any extra help except for the chemical analysis.

SECTION OF BOTANY AND HORTICULTURE.

I. The study of the Flora of the State, special attention being given to:

1. The weeds of the farm and garden.
2. Grasses, native and introduced.
3. The various species and varieties of the genera Oxytropis and Astragalus.

II. The further introduction to the garden of such wild fruits as can be obtained.

III. Nursery test of orchard fruits with a view to the study of the adaptability of varieties to this climate.

IV. Tests of varieties of small fruits.

V. Coöperative work with the Division of Forestry of the United States Department of Agriculture.

Under the first division of the schedule it is much desired that opportunity be afforded for an examination of the Flora of the southern portion of the State. There are several regions that have not been visited by botanists, and information concerning the characteristic plants of these regions is much needed.

Under the third division of the schedule, our lists of varieties of fruits that it seems desirable to add to the present collection, if filled, will involve an expenditure of about $100.

It is, also, proposed to continue the work of last season with different methods of grafting, and with crossing.

ENTOMOLOGICAL SECTION.

I. Collecting and rearing insects for the purpose of determining food-habits and life-histories.

II. Further investigations and collections to determine the Fauna of Colorado.

III. Experiments for the destruction of insect eggs.

IV. Testing new insecticides and insecticide appliances.

V. Experiments to determine doubtful habits and test certain remedies for the Codling Moth.

VI. A study of cut-worms and cut-worm moths for the purpose of determining food and egg-laying habits and finding methods of prevention and remedy.

VII. Experiments for the destruction of miscellaneous insect pests.

VIII. Building up the economic collection through exchanges with other institutions.

IX. Experiments in the Apiary:

(a) To determine the value of sugar as winter stores.

(b) Testing apiary appliances.

(c) Making a collection and list of native honey and pollen-producing plants with notes as to their probable value.

(d) A study of the disease known as "bee paralysis."

CHEMICAL SECTION.

I. The completion of the bulletin on Alfalfa Hay, the work on which is already quite well advanced.

II. The continuance of the study of the artesian waters of the San Luis Valley.

III. Experiments with sugar beets on alkali soil.

Note—The second topic is intended to be the beginning of a study of the chemistry of irrigation waters.

SECTION OF METEOROLOGY AND IRRIGATION ENGINEERING.

I. Continuation of the irrigation survey of the San Luis Valley. It is designed to complete, in 1897, the work commenced in 1896.

II. Investigation of losses by seepage and evaporation from canals and reservoirs.

III. Investigation of return waters of the Poudre and Big Thompson rivers; also, of the St. Vrain and Boulder creeks.

IV. The Duty of Water.

V. Continuation of observations of elements bearing upon agricultural meteorology.

RAINBELT EXPERIMENT STATION.

CHEYENNE WELLS, COLORADO.

		Acres.
1.	General farm garden, including melons, squash, and pumpkins	½
2.	Canada field peas, five or more varieties	1
3.	Cow peas—varieties	1
4.	Oats—varieties	2
5.	Spring wheat—varieties	2
	I wish to test here seed grown by irrigation as compared with seed grown by "dry farming."	
6.	Barley—varieties	1
7.	Rye—varieties	2
8.	Millet—varieties, including German, Common, Hungarian, Japanese, and all others which can be found in time for trial. Also test times of seeding	4
9.	Potatoes—variety test and culture test	2
10.	Beets. Varieties of sugar and Mangel Wurzel	½
11.	Non-saccharine sorghums—varieties tested in small plats	2
12.	Broom corn—variety test	½
13.	Corn—variety test—twenty or more varieties	5
14.	Early Amber sorghum, broadcasted, in drills, in hills	5
15.	Brown Durra	6
16.	Grasses—variety test, including alfalfa	1
17.	One acre is now in fall wheat—33 varieties	1
18.	Rows for testing shrubs and trees to be used as windbreaks. These will include Russian Mulberry, Colorado Artemisia and Russian Artemisia cuttings, Russian Wild Olives, and such others as can be had by planting time	1
	Total number of acres	37½

This schedule covers the available land, perhaps a trifle more, when roads, turning-rows, and yards are deducted from the 40 acres broken.

The missing trees in the orchard should be replaced by selected "hardy" trees. And, if we have the funds, I recommend that 40 trees be bought of the Iowa Experiment station, allowing Professor Budd to send us such as his judgment dictates. Twenty apple trees are needed to replace dead trees and fill out the plat.

Included in culture tests proposed is a modification of Campbell's method of soil culture which is spreading over the semi-arid region so rapidly.

OTHER WORK PLANNED.

1. Testing the influence of a wind-break upon evaporation, and also upon a crop.

2. A continuation of soil study begun in 1896.

3. A continuation of the study of the development of the roots of forage plants which was also begun in 1896.

4. A comparison of seed wheat grown under irrigation with that grown by "dry farming."

5. Coöperation with the different scientific departments of The State Agricultural College in making collections, and in obtaining a greater knowledge of the eastern part of Colorado.

It will be seen that my plan for this year is to test as many varieties as possible. This will cut the farm up into numerous small plats and make a large amount of work in the line of careful note-taking. Much of the planting must be done by hand, also, on account of the small size of the plats. This will increase the labor very much during planting time.

With this schedule, it may be best to employ a hand most of the time from May 1st to October 1st; but, of course, there may not be steady work during May and September.

For wind-breaks, I recommend that Russian Mulberries be planted in thick rows twenty rods apart. At

that rate we could use 3,000 here. They have succeeded here better than any other trees except cherry trees. The Russian Mulberries grow about 5 to 6 feet high and are quite bushy. They could be used at first, and if other trees prove adapted to the use, we can put in the new trees later.

The Division of Forestry of the United States Department of Agriculture might help this Station in testing trees suitable for growth here. I recommend that that Division be invited to use some of the Station land for the purpose of testing varieties of trees.

THE ARKANSAS VALLEY EXPERIMENT STATION.

ROCKY FORD, COLORADO.

CEREALS:

1. *Wheat*—(Already sown.)

A comparative test of varieties: the preliminary trial to be on small plats and the most promising varieties to be carried to practical field tests of an acre or more, the same test to include spring sowing.

2. *Rye*—(Already sown.)

The portion of land above the Rock Ford Ditch and that immediately below, yet too high for convenient irrigation (except during high water) were sown to winter rye, the object being to prepare this area for seeding to alfalfa, a crop which, once established, will often grow on this part of the Station, owing to its close proximity to the ditch. This may also serve as a cultural test of winter rye, as it will probably yield a crop of rye the coming year.

3. *Oats*—

A test of the possibilities of two crops in one season.

4. *Barley*—

Considerable demand is felt in this portion of the State, for a summer feed for pigs. Many farmers are turning their attention to barley. The test on barley the past season at this Station indicates a crop favorable for that purpose. Owing to some of the objectionable features of the common bearded varieties, I would recommend a test of an acre or more of the Phœnix, or

beardless variety, to test its yielding qualities in this portion of the state.

5. *Corn*—

(a) Test on culture. Irrigation *versus* cultivation, and how much of each? The test to continue over a series of years. Test to be planned as follows: Ten acres to be planted early, in as uniform condition as possible, the whole field to receive two cultivations while the corn is yet small, for the destruction of weeds. The field then to be divided as follows: north and south into three sections; the first to receive one irrigation, the second two irrigations, and the third three irrigations. The field also to be divided east and west in three sections: the first to receive one cultivation, the second two cultivations, the third three cultivations; thus making nine sections of the field under nine conditions, from the part that receives one cultivation and one irrigation, to the part receiving three cultivations and three irrigations.

Notes to be kept on the cultivations and rains that fall, and, if possible, a measurement to be made of the water applied to each portion of the field, and a record of the yield of each plat to be reported each year.

(b) Corn on alfalfa sod to prove how long the effects of alfalfa will last. The plat of four acres of alfalfa sod that was planted to come up last year to be continued in corn with same cultivation for a series of years—a record of the yield to be kept.

(c) Test of varieties.

RICE—Test of upland rice—small plat.

GRASS—The establishing of test grass plats of different varieties to be continued; also test of annual forage crops to be made.

GARDEN DIVISION.

VEGETABLES—Test of varieties with notes on cultivation and irrigation. Miscellaneous planting for exhibition purposes.

POTATOES—Culture. Variety tests with different methods of culture and irrigation applied to early, medium, and late plantings.

HORTICULTURAL DIVISION.

OLD ORCHARD—Observations on amount and date of first blooms of varieties; notes on setting and fruit yields.

NEW ORCHARD—Dead trees to be replaced; notes on growth and development.

SMALL FRUIT—Addition to present varieties. Replacing such varieties as failed to grow.

FORESTRY—Adding ornamental trees and shrubs.

ENTOMOLOGY.

Observations on injurious insects; spraying orchard and garden crops; notes on same.

IRRIGATION.

Measurement of water applied to crops. Night *versus* day irrigation; trial on two rows of cantaloups.

BULLETIN PUBLICATIONS.

The first bulletin, under the provisions of Section 4 of the "Hatch Act," was issued in August, 1887. Including two technical publications, making numbers of a special series, forty bulletins have been issued, an average of four each year meeting the requirements of the law. A list of these publications is herewith given:

No.	*Subjects.*	*Authors.*
1.	Reports of Experiments in Irrigation and Meteorology	Elwood Mead
2.	Report of Experiments with Grains, Grasses, and Vegetables on the College Farm	A. E. Blount
3.	Concerning the Duties of the Secretary of The State Board of Agriculture, and Distribution of Seeds	Frank J. Annis
4.	Report of Experiments with Potatoes and Tobacco	James Cassidy
5.	Experiments in the Apiary	C. M. Brose
6.	Notes on Insects and Insecticides	James Cassidy
7.	Potatoes and Sugar Beets	James Cassidy David O'Brine
8.	Alfalfa: Its Growth, Composition and Digestibility	David O'Brine James Cassidy
9.	Soils and Alkali	David O'Brine
10.	Tobacco	David O'Brine James Cassidy
11.	Sugar Beets	C. L. Ingersoll David O'Brine
12.	Some Colorado Grasses and their Chemical Analysis	David O'Brine James Cassidy
13.	On the Measurement and Division of Water	L. G. Carpenter
14.	Progress Bulletin on Sugar Beets	David O'Brine
15.	The Codling Moth and the Grape-Vine Leaf-Hopper	C. P. Gillette

16. The Artesian Wells of Colorado and their Relation to Irrigation .... L. G. Carpenter
17. A Preliminary Report on the Fruit Interests of the State .... C. S. Crandall
18. Index Bulletin .... W. J. Quick
Special Bulletin "A" Concerning Subjects Investigated by the Experiment Station ....
19. Observations upon Injurious Insects, Season of 1891 .... C. P. Gillette
20. I. The Best Milk Tester for the Practical Use of the Farmer and Dairyman ...... II. The Influence of Food upon the Pure Fat Present in Milk .... W. J. Quick
21. I. Sugar Beets .... II. Irish Potatoes .... III. Fruit Raising .... F. L. Watrous
22. A Preliminary Report on the Duty of Water .. L. G. Carpenter
23. Colorado Weeds .... C. S. Crandall
24. A Few Common Insect Pests .... C. P. Gillette
25. Progress Bulletin on the Loco and Larkspur ... David O'Brine
26. Garden Notes for 1893 .... Marion J. Huffington, C. S. Crandall
Farm Notes for 1893 .... W. W. Cooke, Frank L. Watrous
Seeding, Tillage, and Irrigation .... Fred. Huntley
27. The Measurement and Division of Water. (Third Edition, Revised, of Bulletin No. 13) .... L. G. Carpenter
28. The Russian Thistle .... C. S. Crandall
29. Strawberries and Grapes: Notes on Varieties .... Marion J. Huffington
30. I. Farm Notes for 1894 .... W. W. Cooke, Frank L. Watrous
II. Notes on Tomatoes .... Marion J. Huffington
31. Hemiptera of Colorado. (Technical Series, No. 1) .... C. P. Gillette, Carl F. Baker
32. Sheep Feeding in Colorado .... W. W. Cooke
33. Seepage or Return Waters from Irrigation ... L. G. Carpenter
34. Cattle Feeding in Colorado .... W. W. Cooke
35. Alfalfa .... Wm. P. Headden
36. Sugar Beets .... W. W. Cooke, William P. Headden
37. The Birds of Colorado. (Technical Series, No. 2) .. W. W. Cooke
38. I. Sheep Scab .... II. A Few Insect Enemies of the Orchard ... C. P. Gillette
39. A Study of Alfalfa and Some other Hays .... William P. Headden
40. Barley .... W. W. Cooke

REPORT OF THE DIRECTOR.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—The work of the College and that of the Experiment Station, as I have to do with both in executive functions, are so closely connected that a report relating to either must necessarily touch upon some matters bearing upon the other.

In Colorado, the Experiment Station is made a Department of the College. The Executive Committee of The State Board of Agriculture has general control of the work of the Station. The final decision as to the character of the work to be done rests with the Committee. The Station Council, made up of such Faculty members as have to do with those departments of the College whose work touches most directly the agricultural interests of the State, has the planning and immediate supervision of the experimental work for the Home Station and an influential voice in determining what lines of experimental work shall be prosecuted at the sub-stations.

The work of the sub-stations receives but little authoritative oversight from either the Executive Committee or the Station Council. The superintendent in charge of a sub-station prepares a schedule setting forth the experimental work he thinks it desirable to undertake, and such schedule is considered and acted upon by the Executive Committee and the Station Council in joint session. This schedule, as thus adopted, is the superintendent's guide in carrying on the year's work at his particular sta-

tion. Within the year he makes reports to, or seeks advice from, the Executive Committee through the Director of the Station or the Secretary of the Board, both of whom are officially connected with the Station Council.

So close is the connection of some phases of college work and station work that, at times, it is difficult to tell where one ceases and the other begins. There are, including the President of the College and the Secretary of the Board, seven members of the College Faculty who give a part of their time, not definitely determined, to station work. The total sum paid these employés, annually, is $15,900. Of this total, the sum of $3,900—or less than one-fourth—is paid from the Experiment Station Fund received under the provisions of the Act of Congress, approved March 2, 1887.

Secretary Wilson, of the Department of Agriculture, in his report for 1897, says:

> "The stations are by law made departments of the land-grant colleges, but it was not intended that any part of the station funds should be used for the payment of the salaries of the teaching force or for any other general college purposes. * * * It is evident that in some cases the college has encroached upon the station."

In that case "our withers are unwrung." At no time since the Experiment Station was made a College Department, ten years ago, have there been any drafts made upon the "Hatch Act" fund for the salaries of college employés or, in any manner, to support or equip any college department. On the contrary, it can be clearly shown that the Experiment Station, as a Department of the College, has received financial support considerably in excess of the annual appropriation of $15,000 provided for in the Act of 1887.

In order that I might discuss the subject more intelligently, by reason of the statements of others connected actively with our station work, I sent to each member of the Station Council the following communication and requested a reply in writing:—

"Office Director Experiment Station,
Fort Collins, Colo., December 4, 1897.

To the Members of the Station Council:

Gentlemen—What fraction of your whole service, for which you draw salary as an employé of the College and the Experiment Station, is given to the experimental work of the Section which, as a member of the Station Council, is under your personal direction?

An answer *approximately* correct is all that is required. The part of time reported as given exclusively to station work should include work at home and abroad; also, time employed in attending farmers' institutes and in preparing work done therein, in writing bulletins and compiling statistics, and in such correspondence as relates to experimental work.

Respectfully,

ALSTON ELLIS,
Director."

The statements, received in reply, showed that no member of the Station Council gave less than *one-third*, nor more than one-half, of his time to station work exclusively. In this connection it is proper to remark that no station worker, ranked as an assistant, does any teaching or other work that is provided for in the schedule of college exercises. If faculty members engaged in station work were paid therefor in just proportion to time employed and service rendered, from the station funds they would draw $5,450 instead of $3,900 as at present.

For the equipment necessary for furthering the experimental work, the station fund has not been drawn upon to any great extent. Most of the materials and appliances used in the different sections of station work have been bought with money from funds exclusively college. The inventory, recently taken, shows the total value of all station apparatus and supplies, at the Home Station, to be $2,977.26. This sum does not represent an amount equal to $300 a year for each of the ten years the Station has received government support. This station equipment is in charge of the agriculturist, horticulturist, chemist, entomologist, and irrigation engineer, all of whom have membership in the College Faculty. The

value of the college equipment fund in the departments presided over by these faculty members reaches a total of $29,083.29, or nearly ten times the value of all supplies and appliances belonging exclusively to the sections having to do with the experimental work of the Station.

The college furnishes quarters for the prosecution of the experimental work and keeps them cleaned and warmed; provides these quarters with most of the office furnishings needed and keeps them in repair; and not infrequently transfers service which is retained at sole charge on its treasury, into the experimental field to help on station work. From November 30, 1896, to November 30, 1897, fourteen hundred and forty-five letters were mailed from my office, more than one-third of which related exclusively to station business. The stenographer, to whom all my correspondence is dictated, does not receive any of his salary from any portion of the experiment station funds.

The foregoing statements make clear the fact that, in Colorado, no portion of the work of The State Agricultural College is carried on at the expense of the money set apart for station support. It has been asserted that the fraction of time devoted to experimental work, by heads of college departments, before reported, does not exactly, or even with fair approximation, measure the real division of effort given by these college and station employés to the two lines of work they have in charge, for the reason that college work is done on scheduled time while station work is prosecuted in broken periods, thus losing that continuity of thought and effort so indispensable in carrying on any scientific investigation. There is an element of truth in this assertion, but in it but one phase of the question is presented. I think it can be affirmed that most scientific men who give instruction and make investigations at the same time, as do the station and college workers now in mind, have a decided preference for the experimental side of the field upon which they bestow thought and effort. Their reports show a decided inclination, on their part, to emphasize the importance of the sci-

entific and experimental investigations which they have under way and an evident desire to be released as much as possible from the cares and duties of the class-room. The tendency in the direction indicated is too strong to escape notice. It much more than counteracts any loss of experimental attainment by reason of periodic application to the work of instructing classes and supervising laboratory exercises.

If the station work is interrupted by calls upon investigators to leave experiments in which they are interestingly and profitably engaged to give attention to the class demands of students, it is equally true that a call upon a professor, to whom classes are regularly assigned, to engage in any phase of experimental work that takes him from the institution in term time is a detriment to college instruction and discipline. Possibly *all* kinds of work feel the loss of uninterrupted effort, within limits, on the part of those engaged in them. It is sometimes, but not always, true that a morning's unbroken application to conducting an experiment or making an investigation will accomplish more in the way of satisfactory outcome than could be brought about by effort continued through divided periods of a total equal length. Change of work, if not too time wasting and thought dissipating, may not be unattended with good results.

There is a closer connection between the scientific work of an agricultural college and the experimental work of the station connected with it than is usually supposed to exist. The one qualified to conduct experiments in agriculture ought to be one well fitted to give instruction to a class of students studying the subject. The scientific training that gives the chemist ability to analyze soils, waters, fertilizers, and food products makes him all the more serviceable in the class-room or laboratory in the presence of a body of students. The plan of articulating the work of the college and the station as closely as possible is sound in theory and fairly satisfactory in practice. With more money and a larger corps of workers no difficulty would be found in keeping both college and station

work up to a high standard of excellence. The fact is that we can not do the station work that ought to be done in a state like Colorado with the means at our disposal. Our station work, as now planned and executed, costs more than the total of funds that are properly available for its prosecution. That our experimental work covers as large and important field as it does is due to the fact, clearly shown, that the college funds bear no inconsiderable part of the expense.

Prior to the establishment of the Experiment Station, much work had been done by the college employés in the way of investigations and experiments designed to promote the agricultural interests of the State. There was no special fund provided for paying any part of the salaries of those engaged in this work or for meeting any other expenses connected with it. Instruction in the College and experimental work on the farm brought a cost that was met by drafts on the college funds. To-day, were the Government to withdraw its supporting hand from the Station, experimental work at the College would go on, because it is recognized that the agricultural, horticultural, entomological, chemical, and irrigation departments of the College must, under the law, not only provide class instruction for students, but must seek and make known ways and means for rendering more effective and far-reaching every line of industry connected with agriculture. The bounty of the Government, as provided by the terms of the "Hatch Act," enabled the college authorities to widen the bounds of the experimental work before in progress and make it more serviceable to the people for whose benefit it was undertaken.

The Station work has grown in importance and amount; so has the work of the College. The expense of college management has increased but slightly of late years, while the number of students has more than trebled and increased facilities have been called for. A lessened college revenue from the State, owing to a material reduction in the valuation of taxable property, now confronts us on the one hand, while on the other is seen the

pressing need of additions to buildings, equipments, and teaching force occasioned by a largely increased body of students. The teaching work of college instructors has grown because new classes have been formed without a corresponding increase in the teaching force. Every available dollar in the college funds is imperatively needed for college support. Any draft upon these funds for the extension and betterment of station work means the sacrifice of some of the necessary and legitimate work that the College is now doing. To weaken the college teaching force by requiring that portion of it now engaged in station work to devote more time and effort to investigations and experiments in agriculture would simply be to sacrifice one important interest to further another.

Sub-station support has ever been a heavy drain on the experimental fund. At one time four sub-stations were in active operation. Even then it was planned to establish at least two more, and had the plan been carried out the whole United States fund would have been inadequate properly to provide for the maintenance of the sub-stations. A timely cry of warning was heeded. The idea of trying to promote experimental work in agriculture by multiplying sub-station farms was abandoned. There are those having wide and successful experience in what may be termed scientific agriculture who do not hesitate to condemn, in unmistakable terms, the establishment of sub-station farms as a proper means of supplementing the experimental work planned and in progress at the college station. Without entering into a discussion of this question in this connection, I can affirm, what I have said in previous reports, that if it be thought advisable to have sub-stations in different parts of the State, the cost of their support ought not to come from either the United States experiment station fund or from any funds set apart by the Government or the State for the support of the College. The question of government support to the sub-stations has been authoritatively settled. It has been ruled by those whose province it is to pronounce judgment in the matter, that no money received under the terms of the

"Hatch Act" can be legally used in meeting any expense connected with the establishment and operation of substations. The language of the law is clear and unmistakable and the ruling referred to is not the arbitrary expression of a little brief authority.

The officials who control the management of the College and the Station connected therewith are not responsible for the location of a number of sub-stations and their attachment, for support, to the home institution and its treasury. These sub-stations are the products of legislation prompted by local importunity. It was known that Congressional action had appropriated the sum of $15,000 per annum to be used in advancing the interests of agriculture in Colorado through experiment station work, and at once every section of the State felt that it was justly entitled to a share of this government bounty. It is to be doubted whether some of our legislators who voted to accept the conditions of the Congressional Act of 1887, had any clear understanding of their real import. To secure the establishment of a sub-station, in any locality where there was a demand for one, by legislative act was no difficult matter; for a strong and convincing argument in favor of such action was presented when it was shown that all necessary funds had been generously provided by the Government and that no financial support from the State would be required. In only one instance did the State meet any expense connected with the establishment of these substations. The sum of $2,500 was appropriated in 1893 to meet part of the expense of putting in operation the Rainbelt Station, at Cheyenne Wells. At no time has the State made any direct appropriation for the support either of the Home Station or the sub-stations located by legislative action. In so far as station work has been carried on at college cost, it has been a financial charge upon the State, but to no greater extent.

When appropriations for sub-station support could not be secured from the State, and when it was clearly understood that no part of the "Hatch Act" fund was legally available for such support, the Board of Control

was in a position of anxiety and uncertainty as to the best course to pursue. Wholly to abandon sub-station operations was, in view of all the circumstances, not thought advisable; yet the necessity of doing something to reduce expenses at the sub-station farms was apparent. In the hope that the State could be induced later on to extend the management of the stations some financial help, it was decided temporarily to give over active work at the Divide and San Luis Valley experiment sub-stations and to put the premises in charge of capable persons who would give them proper care and pay a nominal rental for their use. W. A. Debold has charge of the sub-station grounds and buildings, at Monument, for the use of which he pays $40 per annum. All station equipments were removed before he entered upon the premises as tenant. The station lands, buildings, and equipment at Monte Vista are now in charge of J. H. Stone under the terms of a lease which will expire March 1, 1899. The rent payments to be made before the expiration of the lease amount to $325. It will require the whole of this sum to pay water-right rents and to make needed repairs on the station buildings. The inventory recently taken shows the value of the station equipment, used by the tenant in carrying on his farm work, to be $246.55.

The larger part of the station lands at Rocky Ford has been leased and upon the remaining portion, about 80 acres, scheduled farm and experimental work has been prosecuted successfully. The year's work of this station was done at a cost to the experiment station fund of $1,586.16. The receipts from sales of farm products amounted to $411.23. The annual salary of the superintendent, not included in the outlay above reported, was $800.

The Rainbelt Station, at Cheyenne Wells, is in charge of J. E. Payne, as superintendent. The total expense of operating the station, for the year ending June 30, 1897, was $1,125.83. It will be seen, from the figures given, that the total cost of operating the Arkansas Valley and Rainbelt stations was $3,511.99. If

from this sum is taken the receipts from sales of farm products, amounting to $411.23, the remainder, $3,100.76, will show the net cost to the experiment station revenue of these two stations for the year reported. Thus it is seen that more than one-fifth of the money received from the Government for the support of *an experiment station connected with the College* is still used to sustain the two sub-stations where experimental work is yet under way.

At the last biennial session of the State Legislature, bills making appropriations of money, modest in amount, for the support of the sub-stations, formerly established by legislative acts, were introduced and referred to appropriate committees. In each case an adverse report came from the committee to which such reference had been made. Explanation was given that the sub-stations could be maintained at the expense of the college funds if authority forbade the use of the United States experiment fund for such purpose.

One of these appropriation bills escaped the general slaughter in committee-room and came up, in innocent garb, for action in the House. The reputed author of the bill was Hon. T. G. Price, representing Kit Carson and Cheyenne counties, who pressed it to a final vote with successful result. The bill made an appropriation of $2,500 for the support of the Rainbelt Station at Cheyenne Wells. The money appropriated by the bill was not to come from the general revenue of the State, but from the Experiment Station funds already under the control of The State Board of Agriculture or any other funds, under the same control, that could be legally employed for such purpose.

This inoffensive looking measure, divested of all verbiage, meant simply that if those in control of station work could not legally use the United States experiment fund to pay the running expenses of the sub-station at Cheyenne Wells they should be forced to meet them by drafts made upon the funds for college support. This measure went through both branches of the Legislature by a vote that must have been very flattering to the vanity of its originators, but it met a well-merited veto when

it passed on to the consideration of Governor Adams. The veto was couched in terse language. It set forth the bad precedent that would be established were the bill to become a law. It was a convincing argument in favor of preserving the integrity of every fund set apart by past legislative wisdom, or by the endowment acts of Congress, for the support of The State Agricultural College.

I desire to see every phase of station work made more effective and far-reaching, but not at the sacrifice of the educational opportunities offered the youth of the State by the College. If one sub-station can claim existence at college cost, why not a dozen? One violation of college financial rights would be speedily followed by another, and another, until nothing would be left to support more than a mere ghost of an educational institution; and, it must be confessed, that this condition of things is just what some people would be pleased to see brought about. The fact is the agricultural college is a new thing under the educational sun and many worthy, well-meaning people do not understand the ends sought to be attained by its establishment. There are many good people, not without a fair share of intelligence, who are firm in the belief that an agricultural college should attempt nothing beyond experimental work in farming. One hears, with tiresome repetition, that the mission of an agricultural college is to teach agriculture and, presumably, nothing else. Whatever one's views may be, whatever his expressed wishes are, in regard to the lines of work proper for an agricultural college to take up and work along, they count for little when weighed against the plainly worded provisions of the acts of Congress under which the land-grant colleges have become a popular and vital factor in our public educational system.

The State having, by legislative action, accepted the provisions of the Congressional acts of 1862, 1887, and 1890, and having thereby been the recipient of government bounty to the extent of thousands of dollars, is not at liberty, in law or equity, to change the conditions

made operative years ago or to do anything to defeat the ends for the furtherance of which those conditions were proposed and, by pledged faith, formally accepted.

It was not the thought of the friends of the "Hatch Act," when that measure was before Congress, that the sum of fifteen thousand dollars annually would meet all the expenses of the experimental work necessary to be carried on in a state desirous of pushing its agricultural interests to the front. The government endowment of an agricultural and mechanical college in a state was not designed to relieve such state from all financial support of the institution. The expectation was that the state would, in the case of both college and station, make liberal appropriations of money to aid in the more efficient prosecution of their work. The sum of $15,000 used in support of agricultural investigations of a scientific nature at a station in close touch with a land-grant college ought to secure results of high and lasting value. One station thus supported and located would become a potent factor in the advancement of scientific agriculture throughout the state. The students of the college, in whose immediate vicinity such work was in progress, would become imbued with the spirit of investigation and would find in the experiment station a means of further education for agricultural pursuits.

The central idea of the "Hatch Act," one well equipped, properly manned, and eligibly located experiment station in connection with the land-grant college, is too self-evidently sound to require elaborate defence. Whether or not the work of such station could be made far-reaching enough to cover the experimental needs in the fields of agriculture throughout the state would depend largely upon the size of the State, the nature of its soil, and the character of its land configurations. Colorado is a State of wide extent and of diversified topography. It presents as great diversity of soil and climate as do Ohio, Indiana, and Illinois combined, and a greater variation of topographical features. If three experiment stations are needed to work out agricultural problems in

the States named, a less number would hardly meet reasonable requirements in Colorado. While I believe that one experiment station of the right kind would do more for our agricultural interests than a half dozen sub-stations such as we have heretofore kept in operation, I am of the opinion that there is pressing need of more agricultural experiment work in Colorado than can be carried on at a single station, however advantageously it may be located and however well its work may be planned and executed.

The Government has provided financial support large enough in amount, under proper handling, to equip and operate a creditable station at the College. If other station work is a necessity, and I think it is, it should be provided solely at State expense. There is need, in the interest of scientific investigation, that the experimental workers in our Station Council have opportunity to visit other parts of the State more frequently. How they can do this under conditions existing at the College is a question that presents difficulties. I have already shown that the College is paying for scientific investigations connected with station work and that it is not financially in a situation to bear an additional burden of that kind. We must recognize facts as they exist, however much we may deplore them. Until the State can come to the financial support of the Station, it is not good policy to seek to extend its work. We must learn to "cut the garment according to the cloth at hand." Desirable as an extension of station work into new fields may be, we must resist the temptation from within and pressure from without to engage in it. A small area well cultivated, is the policy suggested to us by existing conditions.

There is a choice of work that must be wisely made. With the loss of two sub-stations has come opportunity for some desirable concentration of experimental effort. The sub-stations yet in operation are in better condition than ever before. They are, under intelligent management, ceasing to be *farms* in the ordinary acceptation of the term, and are making a creditable showing of experi-

mental results of permanent value. The success of their management is no longer measured by the amount of farm sales reported.

At the Home Station, the work, as I see it, is making steady progress in the right direction. The experimental investigations on the grounds and in the laboratories have been prosecuted earnestly and with effect. The bulletin matter, prepared and widely distributed within the year, covers almost three hundred closely printed pages. The working force of the Chemical and Entomological sections has been strengthened. With new and ample quarters, soon to be available, the Chemical Section will be in condition to meet more fully than ever before the demands for analytic work, both from the other sections of station work and from others having just claims for such service.

Two lines of special work are worthy of mention. Irrigation investigations of practical value have been made in the San Luis Valley and elsewhere. The results of the irrigation survey of this valley, completed last summer, will soon appear in bulletin form. The interest in sugar beet culture, manifested in different parts of the State, suggested an attempt to demonstrate, on a larger scale than ever before, the known adaptability of much of the soil of Colorado to the remunerative growing of sugar beets. Seeds were widely distributed and efforts made to secure their proper handling on the part of those undertaking to plant, cultivate, and render reports of results. The general result was far from discouraging, although it was not what those with high hopes had anticipated. It is now seen clearly that the best way to carry on such an experiment is to make careful selection of those to take part in it and then give their efforts some personal supervision by one well fitted by training and experience for such office.

The work of the new year will be entered upon with renewed earnestness and fidelity. Attempt will be made to give greater practical force to all experimental work which it is proper to undertake with the means at com-

mand. Quality will weigh more than quantity in the scales where the importance of station work is tested. In connection herewith I present for your consideration the reports of the members of the Station Council and those of the Superintendents of the sub-stations located at Rocky Ford and Cheyenne Wells.

Respectfully submitted,

ALSTON ELLIS,
Director.

FORT COLLINS, COLORADO,
DECEMBER 8, 1897.

REPORT OF THE AGRICULTURAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—Herewith, I have the honor to present the report of the Agricultural Section for the past year.

In the report presented to you a year ago, mention was made of a bulletin on the "Birds of Colorado," which was nearly completed. This was finished and issued last March as a volume of one hundred and forty-three pages—the largest bulletin yet issued by this Station.

The call for it has already exhausted the edition. As a result of thus summarizing our present knowledge on the subject and making it accessible to the public, considerable interest has been awakened and a large amount of further material contributed. It is expected to issue this early in January as a supplement to the list.

During the summer a bulletin was issued on "Barley," treating of the varieties, uses, and methods of culture; also, summarizing the feeding experiments made at the College the previous three years on the feeding of barley to steers, sheep, and pigs.

A large part of the energies of the Agricultural Section, the past season, has been devoted to the problem of sugar beet culture in Colorado. It is an old subject for the State, but interest in it has lately increased and the time seemed opportune for making a strenuous effort to prove that Colorado could grow sugar beets of first-class quality and that her people would grow the beets if any one would erect the necessary factory.

Through the kindness of the Hon. Secretary of Agriculture, we were supplied with a large amount of beet seed for distribution, accompanied with mailing sacks and franks, so that the only expense to the College was the labor of sacking the seed and directing the packages. Seed was sent to six hundred and one persons, representing all parts of the State.

In connection with the Chemical Section, a bulletin was issued on the subject of "Sugar Beets" and sent to all those that received the seed. The general result is that sugar beets have received a more extensive trial than ever before in this State.

At the same time several tests were made on the College farm by the Agricultural Section and an elaborate series of tests has been carried through by the Chemical Section on a part of the College farm. Throughout the season the Chemical and Agricultural Sections have worked together at the sugar beet problem to their mutual benefit.

When the crops were ripe enough for testing, a large number of samples were analyzed by the Chemical Section; also, some seventy-five samples were analyzed for us by the Department of Agriculture, at Washington.

Much of this same kind of work has been done in previous years at the College, but this year the rule was made and enforced that no samples should be analyzed until we were supplied with full records of the planting, cultivation, irrigation, and harvesting of the beets. In this way the analysis has value because we have with it the full records of the conditions under which the beets were grown. It became evident very soon that even this was not sufficient, and the writer visited personally several towns and took samples of nearly forty different beet fields, at the same time making full notes of the surroundings and conditions.

The net result of all this labor is, that the beet sugar problem is more complex than ever. It has served to show that the conditions of Colorado are not good enough to grow merchantable beets without the expend-

iture of considerable care and labor. It is also shown that even with the best of care there are several areas that can not raise beets with any profit. While thus circumscribing the area for future investigations, it has pointed out the need of extended experiments on a large scale and especially on a number of farms to determine the variety, the kind of seed, and the methods of caring for the crop that will produce the highest priced beets.

In view of the fact that there is unlimited capital ready to build factories wherever it can be proved that the conditions are favorable, it seems advisable to continue the investigations another season.

I would suggest that three localities be selected in the Arkansas Valley and three in the valley of the South Platte, and that in each of these a field of beets be grown under the direct supervision either of the Home Station or of the Superintendent of the Arkansas Valley Sub-Station for the purpose of making more exact tests on these points than could be gotten from the voluntary work such as has heretofore been employed.

The results of the past season will be digested and presented the coming winter as a joint bulletin of the two sections.

The experiments in stock-feeding have been continued throughout the year. It was expected before this to have a bulletin on "Pig Feeding;" but the material has not accumulated so fast as was expected and it may be several months before it will be in such shape that a satisfactory bulletin can be issued.

Our experiments on the raising of early lambs have now been carried through two seasons. At the close of next spring's work we shall consider the matter as sufficiently tested and make our final report on the operations of the three years.

The results of last winter's sheep feeding were highly satisfactory, both from the experimental and the commercial side. There are now about two hundred head of sheep and lambs on the farm, and the tests arranged for

this winter have reference rather to the scientific side of the question than to the commercial.

In connection with the Entomological Section, further experiments on the cure of sheep scab are being conducted.

Respectfully submitted,

W. W. COOKE,
Agriculturist.

FORT COLLINS, COLORADO,
NOVEMBER 30, 1897.

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W. W. COOKE,
Agriculturist.

FORT COLLINS, COLORADO,
NOVEMBER 30, 1897.

REPORT OF THE HORTICULTURAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I have the honor to submit the following report on the work of the Section of Botany and Horticulture.

The main effort of the section for the year has been in the direction of testing varieties of orchard and small fruits.

In my report of one year ago this work was outlined, and lists of the varieties then under trial, with notes on their behavior as far as tested, were appended. Last spring, by purchase, and by gift from the Department of Agriculture, and from individuals, considerable additions were made to the lists of varieties.

The new apple orchard which was set in the spring of 1896 was in very poor condition last spring, and the percentage of dead trees was large. The injury inflicted by the scant supply of water during the summer of 1896 was increased by the conditions that prevailed during the winter. The fall of rain or snow was very scant; there was no frost in the ground and evaporation from the trees was more rapid than the soil moisture could supply, hence a wilting of the tissues, and the final death of the tree.

All vacancies were filled and a few rows have been added to the plantation. The number of trees set was 344 and but few have been lost during the summer, although the water supply has again been short. The number of varieties now represented is 170, and these

exhibit all degrees of value from excellent to very poor. In addition to the varieties in orchard we have a number of others represented by only one or two scions which were inserted as top grafts in old trees; these will be root-grafted during the winter.

The vacancies occurring in the plum orchard were mainly confined to those varieties which from previous experience we had rated as tender for this region. These vacancies have been filled, and an addition of five rows has been made on the north side. The number of trees set was 267 and there are now represented 131 varieties, 58 of which are new to the collection this season. Most of the varieties planted in the years 1894 and 1895 flowered this year and 37 varieties matured fruit in sufficent quantity to afford a basis of comparison as to value. Careful notes have been kept during the season and it is proposed to arrange these for publication as soon as possible.

The new strawberry bed set last spring contains 42 varieties not previously grown at the station, together with a number of varieties from the old bed which it is desired to test further and to compare with the new acquisitions. The seedlings resulting from the crosses made in 1896 have been given good culture through the season and will produce a crop next year that will enable us to pass judgment upon their merits. Further crosses were made this season from which a large number of seedlings have been secured.

Of other small fruits we have added one new Gooseberry, one new Blackcap Raspberry, one new Blackberry, and four new Currants.

The coöperative experiment with the Division of Forestry of the United States Department of Agriculture to test the relative hardiness of forest-tree seedlings as grown from seeds produced in different sections of the country is under way. Owing to difficulties in securing seeds the department was unable to make the test as wide-reaching as was planned. The number of states contributing seeds for the test is, including Can-

ada, 23, and they represent sufficiently different climatic conditions to make the test an interesting one.

The summer notes show some differences in vigor of growth and in the persistency with which the leaves were held after frost, but the interesting differences will be those that develop after the test of exposure to our winter conditions. Under advises from the department preparations are being made to extend this experiment for the coming season. During the winter such time as could be spared from other work was given to the arrangement of the material collected for the flora of the state. Ninety pages of manuscript have been prepared, and I shall push the work as fast as I am able during the coming winter, but with the limited facilities at hand progress is slow.

There are several interesting regions in the state concerning which we have no botanical information, and I do not know that they have ever been visited by botanists. It would greatly facilitate the work in hand if opportunity were afforded for a visit to these places for the study of their flora. The desired information can only be obtained in this way, and is very essential to any treatment of the general botanical features of the state. That there is demand for information about native plants may be inferred from the department correspondence. The number of plants sent for naming, and the inquiries concerning plants are increasing every year. Attention to these demands requires care and a considerable portion of my time. The questions most frequently propounded are with reference to forage plants and noxious weeds.

The forage question is an important one, and a careful survey of the state with reference to the native grasses could profitably be made a strong feature of the work of the section. The problem of pasture and hay plants for the great park regions, and the relations of the native flora to the flora induced by the systems of irrigation in practice are matters of great practical as well as scientific interest and deserve study.

During the year about 2,000 specimens have been added to the herbarium by exchange. This work could easily be carried further were the time available for arranging and sending out the plants of our list that are called for. Nearly all the work of this kind has been done in the evening, no other time being available. Several desirable offers of exchange we have been obliged to decline.

The forestry experiments of this season offer more of encouragement than did those of 1896. The stock sent this station by the Forestry Division consisted of 17,000 coniferous seedlings, 16,500 deciduous seedlings, and 5,500 cuttings. The coniferous stock was all planted in nursery; some species have done well, while others have entirely failed. The deciduous trees consisted of Aspen, Elm, Birch, Maple, Cherry, Box Elder, Honey Locust, Black Locust, and Mulberry; they were planted according to definite plans and, water being available at the time, the per cent. of loss was small. Most of the stock made a fair growth and the plats presented a creditable appearance through the summer.

Respectfully submitted,

C. S. CRANDALL,
Botanist and Horticulturist.

FORT COLLINS, COLORADO,
NOVEMBER 30, 1897.

REPORT OF THE CHEMICAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I herewith transmit a statement of the work completed during the year, and now in hand, by the Chemical Department of the Experiment Station at The State Agricultural College.

At the beginning of the twelve months just closing, we were engaged upon a study of alfalfa hay. This work has been recorded in Bulletin No. 39, which is independent of and at the same time supplemental to Bulletin No. 35. While the study as recorded in Bulletin No. 39 is complete in itself, there are some questions of great interest, related to the chemistry of fodders and their digestion, which are only mooted or barely suggested. I hope at some future time, not very remote, to be able to take up this same study on a wider basis with the aid of animal digestion. So far as I am aware no other station has, as yet taken up this line of work, but the chemists are working in this direction, trying to perfect methods of investigation so that similar studies may be expected to appear with no great delay.

We have a larger amount of incompleted work on hand than at any other time during my incumbency.

While I do not see when the work will take definite shape for publication, I am trying as opportunity offers, to obtain as much information relative to the waters of the State as I can, with the ultimate object of using it in a study of the chemistry of irrigation waters. To this end we have examined during the year various artesian

and other waters. The number of artesian waters submitted to complete analysis was nine; of river waters, six; of spring waters, four; of well waters, nineteen, making a total of thirty-eight waters submitted to complete mineral analysis. Partial analysis of forty other waters has also been made during the year.

The systematic station work being carried on at the present time is a soil study, which is being made on that portion of the College Farm formerly used by Prof. Crandall for forestry experiments but subsequently abandoned. This work involves the growing of crops on the soil; the making of analyses of the soil; the study of the soil water, and a thorough chemical study of the crop grown. The crop chosen for this year was sugar beets, four varieties, and of other beets, two varieties. The labor entailed by this experiment has proven to be almost beyond our ability to perform and it is doubtful whether we shall be able to get this year's work completed before it is time to begin the field work in the spring. It is our purpose to continue this study for another year, at least, and perhaps for several years if the Committee approves of it.

We have received a considerable number of sugar beets, during the fall months, for sugar determinations. The total number of sugar determinations made from September 1st, to date, is one hundred and eighty-two. The highest percentage obtained was 17.5. The samples received early in the season were uniformly low but later they improved in quality and showed, as a rule, a remunerative quantity of sugar to be present; also, an increase of the coëfficient of purity to such an extent that nearly all of the later samples were marketable beets.

The public continues to make occasional calls for analytical work. We try to accommodate such parties, as far as we can, but our own work is, as a rule, given precedence, especially as the analyses requested have no general interest and no permanent value.

There is no new line of work which I wish to take up at present or during the coming year. I wish in closing, gratefully to acknowledge the support and interest of the administration and Board.

Respectfully submitted,

WM. P. HEADDEN,

Chemist.

FORT COLLINS, COLORADO,

NOVEMBER 30, 1897.

REPORT OF THE ENTOMOLOGICAL SECTION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I have the honor to submit herewith the following report from the Entomological Section of the Agricultural Experiment Station for the year 1897.

EXPERIMENTAL WORK.

The experimentation for the year has been in accordance with the outline adopted for this section. The work undertaken for the purpose of determining the habits and life histories of cut-worm and other night-flying moths was given much attention and a large amount of valuable information gained. I hope to be able to continue the work for several years to come. I sent a paper to the Detroit meeting of the Society for the Promotion of Agricultural Science, which convened last August, giving the more important data obtained in this work. Some of the conclusions to be drawn from the work are the following:

As a rule, male and female moths fly to light or sugar in about equal numbers.

Males fly for a few days, sometimes fully a week, before the females of the same species.

The females are captured more freely before depositing eggs, as is proven by the fact that the large majority of those taken have their ovaries well filled. The idea, that moths that fly to light and sugar are mostly males, and females that have deposited their eggs, is, therefore,

incorrect and any plan that is successful in capturing and destroying moths at light or sugar will lessen the number of caterpillars that they would produce.

Considerable data has been collected, also, in regard to the value of different remedies for the destruction of the Codling Moth, but it will be best to have the experiences of another year before announcing definite conclusions on portions of the work. From the experiments already conducted, it is evident that the use of bandages for the destruction of the larvæ can be made of great service, and that the protection gained from the destruction of fallen wormy fruit is but slight.

Several species of plant lice were unusually abundant on fruit and shade trees the past summer, and considerable attention was given to the testing of the various insecticides for their destruction, and important information gained for future bulletins.

During last winter and spring a large amount of experimental work was carried on for the purpose of determining the habits of the sheep scab-mite and the remedies best suited for its destruction. The results of those experiments were published in Bulletin No. 38.

Experiments in the Apiary have been continued and a portion of the results made public in a paper read before the Society for the Promotion of Agricultural Science meeting at Detroit, Mich., last August, and entitled "Weights of Bees and the Loads they Carry."

NOTES ON INJURIOUS INSECTS.

The Peach Twig-Borer and Fruit-Worm (*Anarsia lineatella.*)—For the past two or three years complaints have come from growers of peaches, on the western slope, of a small worm that eats into and injures or destroys the fruit. On the 7th of last May, I received three packages and as many letters from parties in western Colorado, reporting serious injuries to young shoots of peach, plum, apricot, and almond trees, by a small worm which burrowed into them. The letters were from Mr. A. V. Sharpe, Horticultural Inspector of Montrose

county; Mr. B. C. Oyler, former inspector of the same county, and Mr. W. M. Hastings, of Delta. Mr. Hastings has written me a number of letters during the past three years concerning a worm that burrows into his peaches, but this year was the first that any one has complained to me of injuries to the twigs of the trees. I advised Mr. McGinty, Horticultural Inspector for Delta county, to try bandaging some of the worst infested trees to see if the larvæ could be captured in that way. He afterward sent me a quantity of pupæ obtained in this manner. From what Mr. McGinty wrote me it would seem probable that this method could be used profitably for the destruction of this pest.

This insect has long been known as an occasional pest of considerable importance in the peach orchards of the eastern states and of California. A paper by Prof. A. B. Cordley, of the Oregon Experiment Station, read before the Association of Economic Entomologists last August, at Detroit, Mich., treats of observations upon this insect last year (1896) in Oregon, where it was found to spend the winter in the crowns of strawberry plants, in the larval state, where the last brood in the fall burrows. Putting the above observations together, it would seem probable that the first brood in the spring burrows in the tender, growing shoots of peach, plum, apricot, and almond; the second in the fruit of the peach; and the third, or fall brood, in the crowns of strawberry plants. The larvæ are also known to infest strawberry plants in the eastern United States. The larvæ are very active when disturbed, are dark brown in color, almost black at either end, and measure about one-third of an inch in length when fully grown.

The pupæ sent from Delta county by Mr. McGinty, began hatching into moths freely on the first of June. Peaches received from Mr. Hastings, on July 28th, had the worms only about one-eighth of an inch in length and differing from the mature ones in being much lighter in color.

It is probable that Paris green or London purple may be applied profitably to the trees in the spring when the young shoots are just starting.

The Strawberry Leaf-Roller (*Phoxopteris comptana.*)—This is one of the worst strawberry pests in the states east of Colorado, and I found it to be injuriously abundant at Rocky Ford the past summer, where my attention was called to its work by Mr. W. Frank Crowley, Superintendent of the Experiment Station at that place. Mr. Crowley said that in some patches in that vicinity the damage from this insect had been considerable. The larvæ are brown in color, quite slender, measure about one-half inch in length and live in folds of the leaves. Spraying the plants with Paris green after the crop is gathered will destroy many of the larvæ. The last brood is sometimes killed by spreading straw over the patch and setting fire to it.

The Oak Carpenter-Worm (*Prionoxistus robiniæ.*)—This insect is fast becoming a destructive borer of the cottonwood trees in this State. It occurs both sides of the Range, but as far as I have been able to observe, it is more abundant on the eastern side. In Denver and Fort Collins, I have noticed in particular that the cottonwood trees are badly bored and many are dying as the result. It is doubtful if we know a practical remedy for this insect, and there are some who would rejoice if it would destroy all the cottonwoods. I believe driving wooden plugs tightly into the burrows of the insect, as soon as its presence is indicated by the castings that it works out upon the surface of the bark, will be as efficient and easily applied method as any we now know to lessen its numbers. The females fly quite freely to lights, and in town where arc electric lights are used in the streets, large numbers of females must be destroyed before depositing their eggs.

Plant Lice—The past season has been a remarkable one in Colorado for the appearance of certain plant lice in unusual numbers. The one that attracted most attention was a green louse (*Hyalopterus pruni.*) upon plums. It

attacked both American and European varieties, but as far as their work came under my notice, they were most abundant upon the former. Many trees that set a full crop of fruit dropped it all, and most of their leaves as well, as a result of the attacks of these lice, which literally covered leaves, twigs, and fruit. They remained through the entire summer but were held in check late in the season by the friendly Lady Beetles and Syrphus larvæ, chiefly the latter, which preyed upon them in great numbers.

Black lice upon plum and cherry trees were also quite abundant late in the summer, and the Apple Aphis (*Aphis mali.*) rolled the leaves of apple trees worse than I have known it to do before in this State. Particularly is this true of orchards about Cañon City in the month of August.

The Elm Aphis (*Schizoneura americana.*) which gnarls the leaves of the small twigs near the trunk into unsightly clusters, was also the most abundant that I have ever seen it.

For the lice upon the fruit trees we found kerosene emulsion of the ordinary strength and whale-oil soap, in the proportion of 1 pound to 8 gallons, thoroughly applied, to be very effectual remedies. For the Elm Aphis, thorough pruning away and burning the first leaf clusters should be practiced. Sprays are ineffectual on account of the protection which the leaves give the lice.

The Cottony Maple Scale (*Pulvinaria innumerabilis.*) is sufficiently abundant to call forth inquiry every year, but it became unusually numerous on soft maples in portions of Denver last summer. Trees about the court-house grounds were so badly infested that some seemed to be in a dying condition as the result. While examining the trees, a by-stander asked "What is the matter with the trees? The limbs look as though they had been covered with popcorn," and it would be difficult to describe their appearance better. The janitor in charge of the grounds, removed the greater portion of the scales by means of a

hose early in the morning when there was a strong pressure of water.

The Harlequin Cabbage Bug (*Murgantia histronica.*) was reported to the Experiment Station for the first time, the past summer. Specimens were sent from Kit Carson county, where they were said to be doing serious harm to turnips and cabbages.

Mediterranean Flour Moth (*Ephestia kuhniella.*), which has caused so much trouble in flouring mills, has been sent to me as a bad pest in honey houses, where it is troublesome on account of its attacking empty honey combs. I have not known it to infest bee hives in company with the bees, but I have seen combs badly riddled where they had been stored away with pollen in the cells. The larvæ are not wax-feeders, but pollen-feeders.

Bee Paralysis. For some years past bee-keepers east of Denver have lost large numbers of colonies of bees nearly every spring from a mysterious disease, the cause of which no one has been able to determine. On the 18th of May, last, I received a letter from Mr. Frank Rauchfuss, who, the previous year, lost the greater portion of his bees in a few days. He stated that paralysis was breaking out among his bees again and wanted to know if I could investigate the matter. A few days later I went to the home of Mr. Rauchfuss with a compound microscope and other necessary appliances to make a careful study of the alimentary canals of the bees, hoping to find the cause of the malady. On arriving I found that the disease had subsided so that it was with difficulty that any bees could be found exhibiting the characteristic symptoms. A few were found, however, and an examination showed that in each case the alimentary canal contained large numbers of minute vegetable organisms that were, to all appearances, the spores of some fungus or rust. In healthy bees few or none of these spore-like bodies could be found. For lack of material to work upon, the investigation could not be continued, so we have only a suggestion that possibly the disease is due to the bees gathering and eating the spores of some fungus (rust or

smut) that appears upon certain plants at certain times, perhaps just after a rain when the atmosphere is warm and moist. I mention the matter, hoping that those who keep bees and have this disease among them in the future, will send me specimens by mail for examination, and will also closely observe from what source the bees seem to be gathering their pollen.

BULLETINS.

Bulletin No. 38, giving the results of experiments with scab in sheep, was issued from this section last April. I now have nearly ready for the printer, material for a short technical bulletin describing several new Hemiptera from the State, and giving such notes and records as have accumulated in the department from the capture of butterflies and moths within the State, or from rearing the same from larvæ or eggs. Work has been commenced, also, upon an economic bulletin in which it is my intention to give information in regard to the habits and remedies of those insects that are most injurious within the State.

Respectfully submitted,

C. P. GILLETTE,
Entomologist.

FORT COLLINS, COLORADO,
NOVEMBER 30, 1897.

REPORT OF THE SECTION OF METEOROLOGY AND IRRIGATION ENGINEERING.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I have the honor to submit the following report of the Section of Meteorology and Irrigation Engineering for the past year.

Measurements to determine the increase of rivers from return waters from irrigation were made again in 1896 on the Rio Grande, the Cache a la Poudre, and the South Platte rivers; and in 1897, on the Big Thompson and its tributary, the Little Thompson, the Rio Grande, and the Cache a la Poudre. Measurements on the Arkansas river are now in progress. These measurements are made essentially in the same way. The river is measured at some point above the ditches. All the water being taken from the river is measured, and also the water running into the river from natural sources. If, then, to the amount of water found in the river the inflow be added and the amount taken out of the river be subtracted, we have a remainder which would indicate the amount of water left in the stream. Instead, we find in most cases that the river is much larger than this difference would indicate. In other words that the stream is gaining constantly from many sources, and that many times the gain in the stream becomes of immense importance to the agricultural community of some localities. As the agriculture of the State depends upon irrigation almost entirely, and as the water supply is a limited one,

the determination of the amount of water that may thus return to the streams, the distribution of this water and the loss which affects it, is one of the questions fundamental in our Colorado agriculture. The measurements reported in Bulletin No. 33 gave pretty clear evidence that the increase came from the water which was applied in irrigation, and that about one cubic foot per second was supplied by from 400 to 1,000 acres of irrigated land. The measurements since made have served, in a general way, to strengthen these and other conclusions given in that bulletin. Besides the measurements on the Cache a la Poudre and the Platte, determination was made of the water in the Rio Grande as well, both in 1896 and 1897. The comparisons of the measurements in 1896 indicate some unusual results which might be disturbing in their conclusions, so therefore, I hesitated to report them until confirmed by the measurements of 1897. The results of these measurements indicate that in the case of the Rio Grande the return of water to the river is small. They also clearly show that, for a portion of its length, the Rio Grande is losing a large amount of water from its bed, leaking most probably into the surrounding country. The loss in ten miles amounts to from 75 to 100 cubic feet per second, which under their conditions would have a market value of $40,000 to $50,000. If the water could be saved by storage, or if it had the value of water in the older communities of the State, this water would represent some $200,000 or more. The magnitude of this loss leads to the consideration of some means of saving this water at a cost which would warrant the work by the canals which could use the water thus saved. It may be added, that the measurements made on the Poudre and on the Platte have indicated losses in certain portions of their length, losses which were attributed partly to changes in the stream or to the necessary inaccuracy of measurement. The subsequent measurements continue to show such losses and also indicate that these losses are generally in certain stretches of the river. In the case of these two streams, the Cache a la Poudre and the Platte, the losses

are not great enough to justify means for saving the water. In the case of the Rio Grande the loss is greater: so much so that some method of saving the water may possibly be profitably undertaken.

Seepage measurements were also made upon the Big Thompson, from the cañon 12 or 15 miles west of Loveland, to its mouth at the South Platte river, a distance of thirty miles. The Big Thompson valley is one of the oldest irrigated sections of the State, with a large area under cultivation and a prosperous farming community. Its water shed, though small, has an unusual proportion of elevated mountain area, extending to over 14,000 feet in elevation, and as it has a northern exposure, the stream is one of the best of the irrigation streams. The demand for water on this, as on other streams, is in excess of the supply, and force of circumstances brings great pressure to husband their supplies. The Little Thompson is a tributary of the Big Thompson and the community along it is mostly supplied by water from canals from the larger stream. To determine the total return from the lands irrigated by the waters of the Big Thompson, it was therefore necessary to measure the small as well as the larger stream. The determination was undertaken in November, when most of the ditches were carrying a small amount of water. The measurement shows a gain of 70 cubic feet per second in these streams, the water returning from that applied in irrigation. As the river left the mountains with less than 15 cubic feet per second, it will be seen that at this time, over six times as much water was taken from the stream as came from the mountains. And this is in addition to the supply from one or two natural tributaries.

Measurements to determine the gain or loss from seepage on the Arkansas river are in progress at this date, (Nov. 22,) and the results can not yet be given. A beginning was made in the month of October, but a heavy storm of sleet and snow stopped operations, and these have only recently been resumed. The effect of such a storm is not only to raise the tributaries,—which in the

case of the Arkansas, have immense drainage areas,—and cause the river to fluctuate, but affects the inflow of seepage in the ground. The water shed of the Arkansas rises in both directions from the river, and storms which yield rain at the river may leave snow on the divides, a couple of thousand feet higher, so that the river may not be in a stable condition for a week or more. A peculiar condition of the Arkansas basin depends on the fact that the strata underneath the valley bed dips to the north and away from the river. Whether this will affect the seepage is yet to be determined, but it indicates the possibility that seepage from the ditches on the north side of the river may not return to the river. If such be found to be the fact, it will introduce some important questions into the agriculture of that valley.

I am glad that we have been able to undertake this investigation, for I think no single one will be more important in its effect on the interests of many people and on the prosperity of a larger region than this. This fertile valley is so well adapted to fruit and valuable crops, and the demand for water will be so great, that there is sure to be much bitterly contested litigation, a burden upon the agriculture of this valley. The facts determined by such an investigation will serve, I trust, to establish a basis for comparison in future years, will serve to quiet some apprehension and to forestall some of the litigation which is bound to come. Our measurements will not only be immediately serviceable, but will be increasingly valuable in the years to come. While there are many questions which we can take up with profit, and that are perhaps of greater immediate service, yet I think that no one can study the development of the irrigation in older countries like Spain, or Italy or France, without being impressed with the amount of litigation which has attended the development of irrigation and been a burden upon the agricultural interests. Much of this litigation has been upon questions which were capable of settlement by investigation, but have been blindly settled by uncertain testimony. Much of such litigation could have been saved

either by wise legislation or by a full knowledge of the tendencies of irrigation and of various physical facts which could be learned only by investigation. It would seem a part of wisdom for any institution similar to this, to attempt to determine some of these questions and forestall much protracted and costly disputes which the experience of other countries has shown will inevitably come, and it would seem that in no single way can we give more lasting benefit to our State and its agricultural interests.

The measurements referred to have shown the increase in various streams from the water applied in irrigation. These gains must evidently be connected with the losses from canals and the water absorbed in the process of irrigation, and therefore measurements of the losses from canals and absorption of water applied to crops should give a check upon the gains found in irrigation streams as well as be of importance in their application to the determination of the amount of water needed by crops. The past year has been the first when we have been able to make other than occasional measures of the losses from canals. To do this the plan adopted was essentially the same as that used in determining the seepage gains or losses in streams. Some seventy miles of canal line have been measured during the course of a year and with other measurements provisionally made, we have the results of something over one hundred miles to report. They show in brief that in some cases the losses from canals may be excessive and in fact indicate that there are many cases where it would be profitable for a canal to take measures to preserve the water which is now lost in its carriage. These losses have generally been considered as necessary to the transportation and distribution of water. While true to a certain extent, beyond a moderate extent it is not the case. The seepage from the canals is a pure loss to the canal and by so much lessens its productive capacity, for with intelligent use the crop value of the canal is in proportion to the amount of water it can furnish. We have found different canals in which the loss

has varied from a depth of one foot in twenty-four hours over the canal surface to a depth of over twenty feet in the same time. The average loss from canals in good condition may be put provisionally at two feet in twenty-four hours. Some study has been given to methods of preventing such losses, but experiments on a larger scale are desirable.

In line with these investigations mentioned, observations have been made for the past two winters to determine the amount of losses involved in the storage of waters in reservoirs. For this purpose measurements were made in a number of reservoirs situated within ten or fifteen miles of this place. Bench marks were established in the fall and the elevation of the water surface found with reference to a fixed point. At intervals of two weeks or a month, the lakes were visited and the elevation of the water surface again determined. After allowing for the rainfall which was assumed to be the same as that at Fort Collins, the difference was taken to be the loss from evaporation and seepage. And using the evaporation given by our observations at the College, we obtained an indication of the amount of loss.

A number of reservoirs which were selected as subjects for observations, were partly filled during the winter so that our observations were not successful on all. The losses from seepage as found were less than anticipated, and may be averaged at two feet for the year from the lakes whose measurements were not disturbed. In a few cases it was found that the seepage flowing into the reservoir was sufficient to make up for the loss from the reservoir.

The evaporation from reservoirs has been the subject for investigation for some time. In this case also there are many difficulties to overcome and as the reservoirs are situated at some distance so that they can be seen only once or twice per week, accidents to the evaporation tanks cause a loss of the record for a week or more. Evaporation tanks were placed in three reservoirs during 1897: Lee's lake, Loomis lake and Claymore lake, being selected because each had a boat and were

convenient of access. The observations have not been completely reduced for the season at this date, but it is clearly evident that the evaporation is over one-half greater than from our standard evaporation tank placed in the instrument enclosure on the College grounds. The previous observations of evaporation on the standard tank have shown that the annual amount averages 41 inches. In the reservoirs under observation the temperature of the water is greater than in the tank in our instrument plat, and the wind has freer action. During the winter season when covered with ice the evaporation is about one inch per month.

The expense of the seepage measurements has been small. In the fall of 1896 the measurement was undertaken at a time when I was ill. The expense included the service and subsistence of three or four persons and the use of team and camping outfit for two weeks. Our portion of the expense which was to be one-half, was less than $40.00. The occasion for the small expense was because we have some young graduates who desire experience in this line, willing to devote their time and service at my request, in carrying through such an investigation. The weather in November was anything but pleasant and the temperature below freezing. The expense of the investigation being carried on in the Arkansas valley has been much reduced by the aid given by the different canals and the different water districts of the valley. The water commissioners and the water superintendents and the canals have freely given of their time, have furnished transportation and have aided wherever possible, so that the actual outlay required has been small compared with the expense that would otherwise be required.

Records of the amount of water being furnished by the Cache a la Poudre river were continued throughout the year. This was done by the use of a self-registering instrument placed at the point where the river flows out of the mountains and above all ditches, save one small ditch. The instrument records the rise and fall of the water on a sheet of paper which is turned by clock-

work so that the record of the week is given on each sheet. The clock-work requires winding each week. To do this has involved a trip to the cañon, fourteen miles, weekly, to change papers, to wind the clock-work and to obtain check readings of the height of water. The Cache a la Poudre is one of the most important streams in the State and one of those best deserving of study, not only because of the magnitude of interests depending upon it, but because it is typical of the irrigation streams of Colorado. We have found by comparison that periods of high and low water are closely followed by the other streams in the State, and in fact that the day of highest water in this stream, is often the day of high water in the others. We have in addition a record of this stream since 1884. The first few years it was taken by the State Engineer's office, the rating flume being put in by the water district, by an assessment on the ditches, at a cost of some $1,500. At a time when the State Engineer proposed to drop the measurement, we assumed the burden and have maintained the work since 1890, and have the records which have mostly been automatic since 1884, with the exception of a portion of two years when the Geological Survey attempted to keep the records. I have furnished weekly bulletins of the river for the past few years to the local press, so that the irrigation interests should know something of the stage of water and of the probable changes to be expected. The bulletins were multiplied by neostyle apparatus, until this year when the Fort Collins Courier kindly offered to print slips sufficient to supply the list. The only expense has therefore been that of postage. The reports seem to have been appreciated, for on proposing to drop them last year, immediate requests arose for their continuance. The weekly circulation given to them was not less than 15,000; some bulletins were widely printed and had as many as 100,000 to 130,000 impressions, and while intended for local use were used by papers in all parts of the State.

We have in place an automatic register with which we experimented for one season in attempting to de-

termine its value as a means of recording the rise and fall of the water at considerable distances. To do this required a special wire from this point to the cañon, twelve or fourteen miles away. A telephone line runs nearly to that point at present. The ditches interested bore the expense of putting up the wire. It was placed on the same poles as the telephone wire, but having been strung by other parties, the wire was made at a different tension from the other and continual trouble was found from crossing of the wires to come in contact, so that the line was really not in good order throughout the

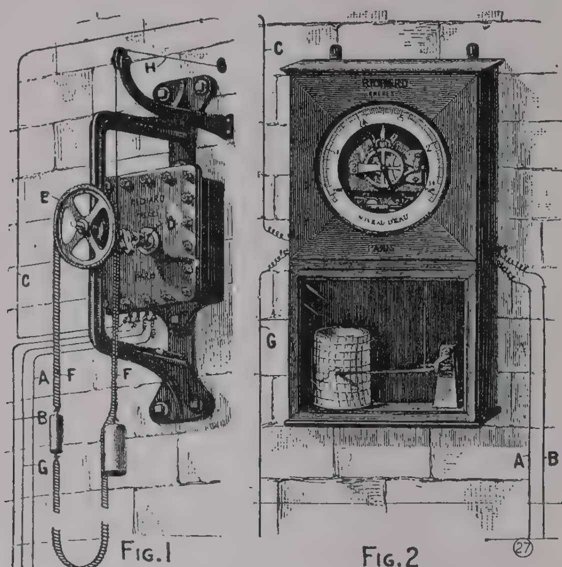

FIG. 1 FIG. 2

season. We obtained enough days when the lines did not interfere to show that if the line were well constructed with strong poles and free from interference from the telephone line that the record would be good. The value of such a record to the agricultural interests in many parts of the State is evident to one who is acquainted with the character of the streams and the importance to our agriculture of using all the water available. As such streams are subject to sudden rises, un-

less timely information is obtained, these rises may pass by the heads of ditches without being used.

The instrument consisted of two parts, the transmitter shown in figure 1, and the recorder shown in figure 2. A battery is placed at the point of transmission and a float, so that as the water rises or falls the wheel shown in figure 1, is caused to turn. Whenever the rise amounts to a fraction of an inch an electrical current is sent which acts on the recorder at the other end of the line, and causes it to change correspondingly. Several ingenious devices are used so that whether the water falls or rises the recorder will rise or fall correspondingly, although but one wire is used.

As the line connecting us with the cañon was not put in condition to make the experiment a success, we have not done anything with the instrument the past year.

In connection with the river records, we have maintained for several years rainfall stations at various places in the mountains, furnishing to observers rain gages, and in a few places, thermometers, on condition that they furnish us with the record. The water shed of the Cache a la Poudre stream rises from an elevation of 5,000 feet at Fort Collins, to an elevation of nearly 14,000 feet at the western portion. Very little permanent settlement exists above an elevation of 8,500 feet. It has been difficult to obtain records from high elevations, although of considerable importance because this is the source of the water supply for most of the irrigated lands. Where we have learned of persons remaining at a higher elevation throughout the winter season, I have attempted to make arrangements with them to make observations during the winter. This has been found to be unsatisfactory, for most of those who are living at a high elevation during the winter, do not care to take the pains required by such work, and the observations are apt to be broken and discontinuous.

I am led to think that it would be possible by a series of observations during the winter season at intervals of

say a fortnight or a month, to obtain at a relatively small expense pretty reliable indications of the supply of water for the next agricultural season. In some years such indications would necessarily be at fault. But records of such type would be of considerable value. The way that such could be taken would be to send some one with instructions to measure the amount of snow fall, to determine the compactness of the snow at certain specified points at different elevations throughout the winter. It would not take long to determine facts sufficient to render it pretty certain what the amount of water during the succeeding season would be: also to indicate whether the water would come early in the season or late, and thus give some indication as to the character of crops which the community could plant. Such information is eagerly sought for by farmers throughout Colorado and upon the information which they thus receive, unreliable and unsystematic as it is, they to some extent depend for indications as to the crops to plant for the succeeding year. In some cases ditch companies have sent men into the mountains to obtain information of this character.

In comparing the temperature records at some of the mountain stations with the river records, we notice the connection between the warm weather in the mountains and the rise and fall of the river. Usually the river at the cañon responds to the change in temperature in about two days. The river is subject to a large tide during the summer season when supplied mostly from melting snow, and the fluctuation in the amount adds to the difficulties in equitable distribution.

We have continued through the year a maintenance of records of the amount of water used on certain farms in the vicinity, keeping the record on the farms on which we have had a record for some years past. It is manifestly desirable in determining the amount of water that is used to take a series of years into account rather than a single one. As we have not had fields where we could control either the methods of cultivation or the methods of irrigation, we have had to take such opportunities as

could be given us by the owners, and such therefore as we could use without disturbance of their ordinary methods of cultivation. The only thing for us to do was to test the amount of water used under their system of cultivation. It is desirable to extend this series of investigation by testing the amount of water required in different methods of cultivation and under different systems of irrigation. But to do this would necessitate some fields which could in most particulars be under my direction. It is manifest that in many cases much more water is used than is required, and there is no doubt that in the case of many crops, better quality of crops could be obtained with a more economical and more judicious application of water. The systems of irrigation used in Colorado, and the systems of distribution, are often extravagant in the use of water and can be improved in many cases very greatly. We have not so far entered into the details of irrigation practice, but hope that such may be taken up and complete studies be made of the conditions governing them. In such cases the coöperation of the chemical department, in the analyses which should be necessary, would be desirable.

It is evident that the study of the questions pertaining to irrigation involve the study of other problems, and among these is that of the ground water. For several years an instrument has been kept in a well which was originally sunk to obtain water for pumping. A record has been maintained continuously. The changes in this are very suggestive and show close connection with the rise and fall of water in a neighboring ditch located on higher ground. During the past summer several holes in different directions from the main well were sunk and records kept to determine the changes and inflow of the ground water over a considerable tract. The record of the past season was tentative, the object being to obtain a better idea of the extent of the problems involved and to gauge the means needed to make a more serious study. It, however, leads to a clearer apprehension of the connection of the movement of our underground water with the seepage of lands and the movement of seepage water.

The investigations in the San Luis Valley begun in the summer of 1896, were continued during 1897, and on the lines planned last season. This valley is one of great extent, covering nearly 3,000 square miles in the portion free from mountains, and has a water shed flowing into it of something like 5,000 square miles in addition. It forms an immense region in which the conditions are peculiar, and in which the methods of agriculture are to some extent special. The questions relating to the water supply and the problems connected with irrigation are different from those of most parts of the State. I was disappointed in obtaining the help expected early in the season, and in consequence we did not accomplish much before the close of the College term in June, when Mr. Trimble went at once to the valley and remained for the summer season. Mr. Stannard also stayed about a month in the valley, besides the time given by myself. With the large valley the distances required to drive are very great. An approximate estimate places the amount in the neighborhood of 4,000 miles by horse and wagon. One of the most important questions connected with the water supply is that of sub-irrigation. The valley is the bed of an ancient lake and the surface is slightly basin shaped, of extreme uniformity and with the soil near the edges so pervious that there have been almost no drainage channels to cut up the valley. The debris of the ancient lake which settled in the bottom is very deep, some artesian wells near Alamosa having gone to a depth of 1,100 feet without reaching rock. The deposits consist of layers of gravel and clay of varying thickness. What appears to be the bottom of the lake shows in many places in the valley and is in all places not far from the surface. When water is applied in irrigation it sinks through the surface soil until it strikes this impervious layer and then spreads laterally, but with the surface so nearly horizontal the water is at nearly a uniform distance from the surface. This condition has caused the method of irrigation which locally is spoken of as sub-irrigation. Some of the lower lying lands in the lower part of the valley are being

made too wet by the process. The sub-irrigated section has gradually spread, as the soil underneath has become filled. Of the hundred or more streams flowing into the valley from the rim of mountains on all sides, nearly all sink and disappear at the borders. It has been questioned as to what became of this amount of water. And when in addition is considered the volume from the Rio Grande distributed through ditches, and which, as already mentioned, does not reappear in the stream, the final disposition of this water is still a question. It seemed quite clearly evident last year that all the water must pass through the cañon of the Rio Grande, which is a box cañon of many miles in length formed of volcanic material. The evidence of the artesian wells is clear that there have been two different lakes at different times. The one lasted for a long enough time to be filled with sediment to a depth of 600 or 700 feet. Afterwards, by volcanic action at the lower end of the valley, the valley was then dammed up and a lake existed for a long enough time to deposit about 400 feet of sediment. At the lower end of the valley are found places where the lava overflowed a deposit of sand, baking it into a natural soft brick. The great amount of water passing into the valley and not yet completely accounted for suggests the possibility that the first lake may have much greater extent than the present valley and that the second overflow of lava may have covered a deposit of sand of great extent, and while damming up the lake in Colorado may have left an under channel of porous sand or sandstone, giving outlet to considerable water where cut across by some of the streams in northern New Mexico. This has not been verified.

There was found to be a general impression that a portion of the valley which has become water logged could not be drained. Through the kindness of the Engineers of the Rio Grande Railroad and of the aid of Engineers of the Canal Companies who placed their level notes at my disposal, I was able to obtain the elevation of most parts of the valley sufficient to make a contour

map which has been prepared but not yet published. This was sufficient to give the elevations of most of the valley west of the Rio Grande railroad extending from Alamosa to Salida. In order to learn the depression of the elevation of the lowest part of the valley, a line of levels was run from Mosca east to the San Luis lakes. In this eight miles a fall of nearly 40 feet was found. In connection with the other levels which we have, this shows that there is a fall enough for drainage to run off the surplus water or to construct drain ditches which will run water into the Rio Grande below Alamosa.

We attempted to obtain sufficient record of the ground water or of the water of sub-irrigation to compare this with the amount of water distributed by the ditches and from the river. From the difficulty of obtaining records and the extent of country traversed, it is not possible to make deductions on this point that will be beyond question. The artesian wells of the valley are numerous and obtained at a moderate cost. We have over one thousand whose location is known, and many others whose locations are approximately known. In a portion of the valley near the eastern side there is considerable area in which the water is bad. It is, I think, an important conclusion that in this portion of the valley, by extending their wells deeper and casing off the brown water, as they term it, that they may obtain good and pure water.

The meteorological observations it is not necessary to detail at length. Those which have been undertaken have been more especially those which bear upon agricultural meteorology. This includes temperature and more especially the questions pertaining to moisture, the amount of rainfall, of humidity, and of evaporation, and also the question of sunshine and solar intensity. Records of soil temperature have also been taken. Numerous other records are maintained.

Evaporation records have been made by placing a tank three feet cube in the ground and nearly filled with water. During the summer season the measurement of the surface of the water is made twice each day by the

hook gauge, by the aid of which the elevation of the surface can be obtained to within a hundredth of an inch. During the fall, observations are made once per day, and during the winter, once a month. A record is made of the temperature of the water and of the highest and lowest temperature during the day. An anemometer is placed close to the tank and this is connected with the recorder in the office and records side by side on the same sheet with the instruments placed on the top of the College tower. These measurements show a loss of water amounting to about 41 inches per annum, from evaporation from this tank.

The number of hours of sunshine has been measured at this station and at the sub-station, but its records have not been reduced for the past two or three years. The records may easily be taken with almost no increase of labor, and will form a valuable basis for study, if time, later serves to make a measurement of them. I have thought it desirable to continue these and other measurements. It is necessary to say that the value of such records increases very much with the number of years record, because we then have data which will more nearly give the average features of the climate. The method of measurement has been that previously used, which has been the use of the Pickering photographic recorder. This is in effect a small camera, semi-circular in form, one for the forenoon and one for the afternoon sun. Inside is placed a sheet of blue print paper on which the path of the sun is indicated by a line. When the sun is covered with clouds no action is made on the paper, consequently the length of line serves to indicate the amount of sunshine. Each night the instrument is set for the next day, so that each day's record falls on a fresh place. The instrument is not entirely satisfactory from the fact that no record is made during the early morning or evening. The records show what is well known, a much greater amount of sunshine here than in the eastern States. That this, together with the intensity of sunshine, must be connected with the active growth of plants, is too well known to

need discussion. But the quantitative connection between the amount of sunshine or the intensity of solar energy received by us, and the rate of growth of different plants is still to be determined, although such would be of great importance to a knowledge of the processes of plant and crop growth. While we have not expected to be able to use these records for this purpose without at least the accumulation of a much longer period, we have obtained them in the hopes that they might be available in the future for such use.

To measure the solar energy, we have used the Arago-Davy conjugate thermometer, which consists of two thermometers of similar graduations and with bulbs of exactly one centimeter in diameter. One of the bulbs is covered with lamp black in order to more completely absorb the solar energy. Each of the two thermometers is placed in a glass enclosure entirely surrounding it, and the air exhausted. The instruments are placed with their bulbs uppermost, pointing to the sky. The radiation is absorbed more freely by the blackened bulb and its indications will be higher than the bright bulb. The differences in the readings of the two thermometers then give the means to determine the intensity of the radiation from the sun. The instrumental constant which is needed to be known before the readings can be interpreted and expressed in units of force or in heat units, has been found by making observations at five-minute intervals throughout the day. Allowing for absorption, as the rays pass through different thickness of the atmosphere at the different times of observation, the constant is derived. We have found the constant of our set by such process and, what was not expected, the constant was found to be almost identically the same as that found by Ferrell for a similar set.

It is not generally realized how great the solar energy received by us is. Engines have been made intended to work by sun's heat and have been put in successful operation at different times for a series of years, both by the French admiral Mouchot and by Ericsson,

who spent the last years of his life in attempting to overcome the mechanical difficulties.

The measures show that for at least eight hours per day on a sunny day, the energy received from the sun averages considerably more than one horse power per square yard. This energy is very largely used in the growth of plants and the connection between these is a most important question to be found in the investigation, although it is not impossible that in the sunny regions of the West that important economic applications may be made of the sun's heat as a source of power. While interfered with by clouds it is as much to be depended upon as the wind which is such a common source of power for small operations. We have also kept records of the sun for the greater portion of the time, with a maximum registering solar thermometer. This instrument registers the greatest heat of radiation of the day but the reading when obtained is uncertain in interpretation. And while the record has been to some extent desirable it is of unsatisfactory scientific value. We have had much trouble in preserving instruments of this type. Nearly all the thermometers have been broken by the great expansion of mercury, the maximum reading running not infrequently to 160 degrees.

The Draper sun thermometer also belongs to the station. This instrument uses a compound bar made of two metals exposed to the sun. The heat absorbed causes the bar to vary in curvature, and as one end is fixed then this end moves on a lever and indications are recorded on a sheet moved by clockwork. In moving the instruments to new quarters, they were dismounted and a portion was broken, and considerable time was required to replace it. I plan to again mount the instrument.

In connection with agricultural meteorology, we have also maintained the record of the soil temperature at different depths in the ground. Three sets of thermometers have been maintained until within the past year. One set was in our instrument enclosure, a second placed on high unirrigated ground near the College

barn, and the third set in low ground between. The latter two sets have been read but once weekly, the former set is read twice daily. During the past year some person or persons wantonly destroyed one set of instruments in the low ground. This set had remained there for eight years without previous disturbance. The temperatures taken include temperatures from near the surface to a depth of six feet.

The other records taken have included the other measurements taken of thermometers, of wind, and of frost. Self-registering instruments have been used where possible, but for the past few years the funds available have not much more than sufficed to maintain the equipment. The instruments at the sub-stations have been mostly supplied from this section and when breakages have occurred, instruments have been replaced when we have had extra ones on hand. It is desirable to have extra instruments in order to be able to replace any breakage and also in order to have the opportunity to test every instrument before it is issued.

One of the instruments we are supplied with is the statoscope, which may be termed a magnifying aneroid barometer. The instrument records any change of the pressure of the air on a greatly magnified scale. During ordinary conditions of the weather the record is a smooth and uniform line. In the case of hail or thunderstorms or the more violent wind storms, the change becomes very marked and the record of the instrument indicates the violent perturbations existing in the atmosphere. A plate shown herewith represents the record of the instrument during a violent wind storm, when the velocity of the wind reached 60 miles an hour. The scale is an open scale so that the length of the diagram is less than one hour. And the distance between the curved lines is only 30 seconds. It will be noticed that the fluctuations are exceedingly violent, some indicating a rise in pressure of several millimeters, and some indicate a depression of as great an amount. These violent barometric fluctuations are coincident with the violent gusts of wind which occur in such wind storms. I have

not clearly satisfied myself whether these fluctuations precede or follow the violent gusts. The differences in time in either case is exceedingly small.

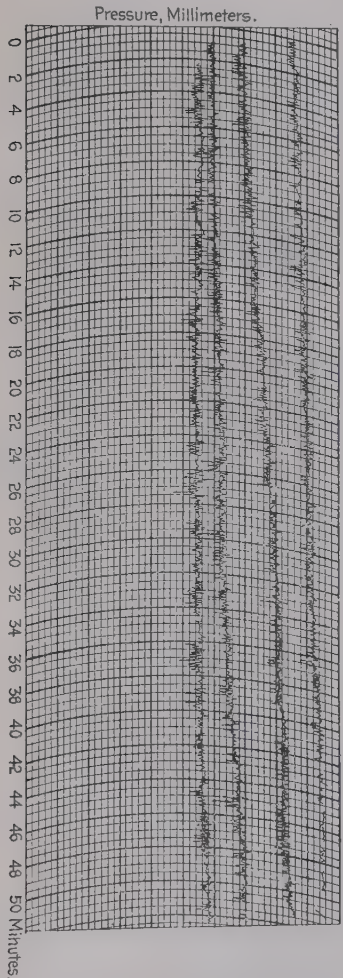

Diagram No. 2.

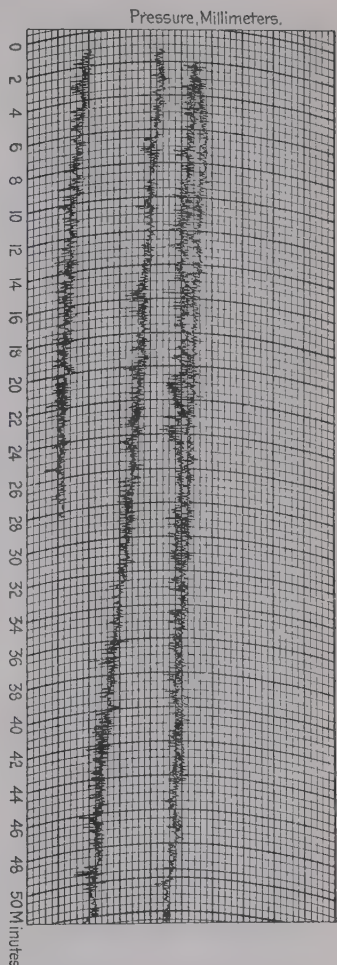

Diagram No. 1.

The sub-stations have each carried on observations to some extent. These include more especially the observations of temperature, of humidity, of rain and frost. The superintendents have so many other details

to attend to that they can not attend to many of this nature.

In order that these observations should be made so that the records can be compared with the records here, it is very desirable that they should be made on the same system and with similar methods of exposure the same. To do that and to make the records valuable for this purpose, the meteorological portions of this station should be inspected by some one from this section at least once per year, in order to suggest or direct such changes as may be needed to make the observations of scientific value. Unless they are under best conditions the observations lose most of their value.

In addition to the reports from the sub-stations, a number of voluntary observers have furnished us with observations from different points in the mountains. The principal element which they observe is rainfall. These observers were originally obtained in order to study the changes of rainfall in our mountain watershed and to obtain fuller information of the changes in precipitation from the plains to the summit of the mountains, in order to know more fully the characteristics of the precipitation which supplies our agricultural interests with moisture.

The station report can not be prepared without the corresponding College work being mentioned, as the connections of the two are so intimate and the work of one so supplements and affects the other that both the time and thought given to one have constantly in view the needs of the other. From the beginning of the College year in September until the close of the College year in June, the demands of classes require a large amount of time and energy and diminish the time which can be given to work of the experiment station, either in observation or in study of the data which has been obtained with the hope of digesting for publication. The fall term is the one with fewest classes and with some available time in the afternoons. For nearly all the remainder of the year the writer has conducted from two to

three recitations personally in the forenoon, besides the immediate charge of one or two afternoon classes in field or laboratory work of two hours each. This is in addition to the classes conducted by the assistant which require more or less thought and attention. During such time it is manifest to one accustomed with College work, that there can be little attention given to investigation, and that effort must mostly be confined to the maintenance of the routine work and the continuation of the line of observations previously planned. The reduction of observations and the obtaining of results from them which shall be of value, require the freshest of attention, and is not such work as can be done under conditions of mental fatigue or jaded attention. If in addition to this is added the correspondence which ought to be attended to, the demands are more than can give the most fruitful results. Correspondence of this character involved by the needs of College work or of the experimental work, or questions referred to the writer from different people involve usually not less than 500 or 700 pages of copy book per annum, and in some single months may run from 100 to 150 pages. Some of the work could be done by cheaper help and in no single way could the work be aided than by authority to employ either some one to aid in the field instruction in the afternoons, or in the correspondence which devolves upon the Department. By so doing, the afternoon of the head of the section, could be freed from details which require almost the entire time and energy during at least two terms of the year, and, under supervision, the results ought not to be much less satisfactory. For a portion of the time of the past month, through permission of the purchasing committee, aid has been had in stenographic work for a few hours per day, and the relief from fatigue of such work has permitted much more time to be given to work that can not be done by proxy. So much so, that I think such aid will give most excellent results if it can be had for a few hours per day for a large part of the year.

I ought not to close this report without acknowledging the help received from Mr. Trimble, the efficient as-

sistant in this section, and from Mr. Stannard, assistant in the corresponding College department, who has aided in the work in the San Luis valley during the summer vacation and at other times by constructing diagrams and charts. Many more have given freely of their time and means to aid in the investigations. Among the volunteer observers have been Mrs. F. W. Sherwood of Glen Eyre, Mr. S. J. Peery of Westlake, P. H. Boothroyd of Arkins, Rev. W. H. McCreery of Loveland, and C. E. Lamb of Estes Park. J. H. McClelland of Fort Collins has permitted us to continue the use of his fields in determination of the amount of water used; Dr. E. A. Lee of Fort Collins has freely given the use of his lake and boat in evaporation observations, and so has Prof. C. P. Gillette; Capt. W. M. Post has allowed the use of his farm for observations on the duty of water; R. W. Hawley and Henry Calkins, graduates of the Engineering Department of the Agricultural College, aided in the measurements of the seepage in the Platte valley late in the fall of 1896, and donated their time for that purpose; P. J. Preston, also a graduate and assistant to the State Engineer, took great interest in that work and advanced the expenses at the risk of reimbursement by the legislature of appropriations to that office in the spring; Mr. Preston has also taken great interest in the measurement on the Arkansas river, and without his aid and acquaintance of the river and of the local interests it would have been difficult to have undertaken the measurement; Water Commissioners J. A. Trulove of Florence, C. W. Reece of Pueblo, S. W. Cressey of Rocky Ford, gave freely of their time and energy and furnished transportation by team, in carrying on this work; Messrs. C. H. McHarg, superintendent of the Bessemer ditch of Pueblo, and Hon. J. S. Greene of Pueblo; W. C. Burke, receiver of the Fort Lyons Canal, of Las Animas; W. M. Wiley, manager, and E. C. Hawkins, chief engineer of The Great Plains Storage and Irrigation Company of Holly, also aided by furnishing teams and transportation, and in various ways. The list of others who have aided to a greater or less degree would be a long

list, especially in the San Luis valley. Mr. J. H. Nelson, C. E. of Loveland also helped very materially with information and freely furnished his time for a number of days in helping on the Big Thompson seepage measurements.

Also to H. Michelson of the Union Pacific, Denver and Gulf, to S. K. Hooper of the Rio Grande, and to J. E. Frost of the Atchison, Topeka and Santa Fe, we are indebted for ourself and assistants for transportation, without which it would have been difficult to have carried on the work on account of expense.

The aid received from the various gentlemen above mentioned is such that the cost if paid for would run up to many hundreds of dollars.

Thanking the committee for the support which they have given to the various investigations, and to the Board for their support, this report is

Respectfully submitted.

L. G. CARPENTER,

Irrigation Engineer.

FORT COLLINS, COLORADO,

NOVEMBER 30, 1897.

REPORT OF THE ARKANSAS VALLEY EXPERIMENT STATION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I herewith present to you the Tenth Annual Report of the Arkansas Valley Experiment Station:

From records of work on the station prior to my taking charge, August 1st, it appears that the schedule was not submitted until May 1st, at which time Superintendent Blinn resigned, leaving the station without a manager from that date until May 15th. Owing to these circumstances, planting did not begin until after all crops should have been planted and it was impossible to carry out in full the schedule of work the past season. For the same reason very little of the work done has given results worthy of publication.

The soil on a large portion of the farm shows signs of having been given too much water the fore part of the season, which has caused it to become deadened. The soil on most of the station is of such a character as to require but little soaking in irrigation. At present the land is being plowed so that the action of air and frost during the coming winter may put new life into it.

CLIMATIC CONDITIONS.

We have had a most favorable season throughout. The last winter gave more snow than usual, which left the soil in good condition for plowing. Spring started out about two weeks earlier than usual, the summer season

was refreshed with occasional showers, though not enough rain to damage hay, and the first frost came October 11th, followed by no killing frost until October 19th. About eight inches of rain have fallen thus far this year. Crops generally are above the average.

AGRICULTURAL DIVISION.

Wheat—Twenty plats, of $\frac{1}{3}$ of an acre each, were prepared and sown to as many varieties of wheat Sept. 23 to Oct. 7, 1896. No record is left in the office of treatment of these plats during the fall and winter. Water was applied to the crop April 5th, May 4th, June 1st, and June 21st. The Turkish matured earlier than the other varieties and was cut July 1st, the balance of the plats being cut July 13th. The following table shows the yield and weight per bushel of each kind:

No. of Plat.	Name of Variety.	Yield per Acre.	Pounds per Bushel.
1.	Royal	14.38 bushels	49.43
2.	Gypsum	14.87 bushels	53.87
3.	Red Mediterranean, (winter-killed)	....	.....
4.	India No. 2, (winter-killed)	....	.....
5.	Uxbridge	26.46 bushels	50.29
6.	China	10.64 bushels	54.05
7.	Australian	13.71 bushels	49.65
8.	India No. 6, (winter-killed)	....	.....
9.	Improved Fife	29.48 bushels	52.30
10.	India No. 3, (winter-killed)	....	.....
11.	Defiance, (winter-killed)	....	.....
12.	Turkish	39.04 bushels	59.23
13.	Feldspar	9.46 bushels	57.61
14.	India No. 5, (winter-killed)	....	.....
15.	Ontario, (winter-killed)	....	.....
16.	Amethyst	17.17 bushels	57.31
17.	India No. 11, (winter-killed)	....	.....
18.	Canadian Velvet Chaff	31.49 bushels	53.76
19.	Red Russian	32.12 bushels	57.88
20.	Clawson	32.12 bushels	52.25
	Averages	22.58 bushels	54.40

The Turkish, Red Russian, and Clawson were the only varieties in the lot that were thought worthy of further attention in this section and they have been carried to a practical field test. The Turkish wheat is the principal variety grown in Prowers county, fifty miles further down the valley, and we have information of a yield of this variety grown in that section the past season which gave 57½ bushels per acre, and personal knowledge of a field of 100 acres in the same district which produced 3,900 bushels. The quality of the flour made from it would also indicate that, so far, the Turkish wheat is the best variety that has been thoroughly tested in this valley.

Ten varieties of Russian wheats were received from the Division of Vegetable Pathology, U. S. Department of Agriculture, and sown in small plats Oct. 5th, 1896. They were irrigated March 26th, May 20th, and June 21st, and cut with a cradle July 15th. The following table shows, in a brief way, the results:

No. of Plat.	Name of Variety.	Place From Which Seed Was Obtained.	Yield per Acre.	P'ds per Bushel.
1.	Bearded Winter	Kharkov	29.34 bu.	43.22
2.	De Theisse	Orlova	33.10 bu.	47.99
3.	Red Girka	Ekaterinoolar, (winter-killed)	....	.....
4.	Pulavka	Gradno	24.86 bu.	48.00
5.	Red Winter	Samara	27.25 bu.	52.63
6.	Saxonka	Poltava, (winter-killed)	....	.....
7.	Winter Girka	Samara	25.50 bu.	60.00
8.	Chernokaloska	Kursk, (winter-killed)	....	.....
9.	Belakoloska	Kharkov, (winter-killed)	....	.....
10.	Yx	Kharkov	26.33 bu.	61.00
	Averages		24.40 bu.	52.14

I do not consider that these varieties have been given a fair test and have therefore continued the test in small plats. Several of them gave promise of becoming valuable additions to our list of varieties of wheat.

Spring Wheat—A plat of half an acre was planted to selected seed Amethyst wheat April 21st. Two irrigations were given and the yield was 27.38 bushels per acre.

Barley—Half an acre was sown to Phoenix barley April 14th, irrigated three times, harvested July 13th, and gave a yield of 26.18 bushels per acre, as compared with the Guy Malye and Black barley under same treatment, the former yielding 14 bushels and the latter 18.4 bushels per acre.

Corn—A field of a little less than four acres of the Golden Beauty corn, planted on alfalfa sod to prove how long the effects of alfalfa will last, gave the following results. The tract had been plowed up and a crop of corn grown thereon last season. Two cultivations and as many irrigations were given in 1896, the yield being 39 bushels per acre. This season the crop was given somewhat better care, receiving three cultivations and three irrigations, which should under ordinary circumstances be the minimum number of cultivations for corn in this section, irrigation of course depending on climatic conditions to some extent. The yield amounted to 46.1 bushels per acre.

Some nine different tests of *irrigation versus cultivation* were anticipated in the schedule, but owing to an uneven stand in one-half of the field the experiment was carried out in part only. The entire field was given three cultivations, the irrigations being given as planned, with the following results: No. 1, irrigated June 25th, Aug. 14th, and Sept. 14th, yielded 45.35 bushels per acre; No. 2, irrigated June 25th, and Aug. 14th, yielded 45.53 bushels per acre; and No. 3, irrigated only once, June 25th, gave a yield of 33.23 bushels per acre. This test has only added another proof to a fact well known by the farmers of the Arkansas valley, which is that corn requires moisture when filling out the ear, although an over supply while maturing is of no value. With more cultivation this entire field would doubtless have been better off with no irrigation from the time the ground was plowed for planting until the tassels had made their appearance.

HORTICULTURAL DIVISION.

Apples—The apple crop was exceedingly small, very few blossoms appearing on most of the trees. The Mis-

souri Pippin, Ben Davis, Wine Sap, and Tetofski were about the only varieties having a full crop in this section. The reason for the failure can not be assigned to any known cause, the climatic conditions having been, to all appearances, most favorable for all kinds of fruit.

Other Fruits—A few seedling peaches produced an abundant crop of very fair fruit, the peach crop generally being good. Several plum trees of the Chicasaw variety were loaded to the ground. Grapes had about half a crop. These, with a few strawberry plants and a small raspberry patch which fruited profusely, complete the list of bearing fruits on the station. The fruit crop throughout the Arkansas valley is good, apples being a partial failure only in a small portion of it.

New Varieties—A very commendable line of experiments was started here, in the spring of 1896, which I hope to see renewed. It consists of the planting of new and promising varieties of fruits. The first installment covered about five acres of ground. The list was the finest that has ever been planted in the State, but owing to the lateness of the season much of the work was lost, and the plats not having been replanted last spring, not more than sixty per cent. of the trees, and less than five per cent. of the small fruit plants, are now alive. This division of the work is one which is of the most vital importance to the Arkansas valley, as well as to other parts of the State, and it is my opinion that more good can be accomplished by devoting a larger share of the time and ground in use on this station to horticultural experiments, than to those lines of general farming in which the difference in climate between here and the Home Station at Fort Collins, becomes a factor of much less importance.

INSECTS AND DISEASES.

Owing to the shortness of the apple crop the Codling Moth has appeared proportionately more plentiful than usual in this section. The few trees bearing fruit on the station were sprayed twice, and some observations of the larvæ under bandages around trunks of trees were made,

the results of which have been duly reported to the Division of Entomology, at the Home Station.

The first flat-head borers known to have been found in this section were discovered in apple trees in the old orchard on the station, and there is evidence that they have been working in some of these trees two or more years.

Strawberry leaf-rollers, which have been doing considerable damage in the patches around here the past two seasons, seem to be the only ones that have been located in the State.

The leaf-hopper and grape caterpillar have been more numerous than usual.

Owing to frequent light showers and warm, damp days, the conditions have been most favorable for the development and spread of blight, which, having obtained a good foothold during the season of 1896, has given the orchardists in this section the same experience that it has given those in other sections of the country in years past. The trees on the station were in a condition to be most susceptible to the attacks of the disease, having made a rank growth last season and the fore part of this, and it is only by close and frequent cutting that the worst blighting varieties have been saved. The Clapp's Favorite pear trees have had to come out by the roots, as have also Paul's Improved crab apple and occasional trees of standard varieties of apples.

The tomato worm was more numerous than usual, as was also the hard-shelled squash bug. A field of two acres of sweet corn was particularly free from worms, which suggests the idea that by planting a large quantity in one place a crop of roasting ears can be produced which will be fairly free from these pests.

CONCLUSION.

Much of the work that has been done on the station during the past nine years has undoubtedly been lost, as a very meagre record has been left, outside of the annual

reports which have been published. I have, therefore, adopted a very complete system of keeping the records of experimental work whereby any new man taking charge will be able to take up the work where it was left off, which has certainly been impossible during the changes which have taken place the past season. It is to be hoped that the conditions under which the work has been conducted this year will not occur again, as the station can not but go backward under such an arrangement. The changes, as you are well aware, have taken place at a very awkward time as far as the experimental work is concerned. The work of a sub-station, to be of any value, must reflect credit on the Superintendent, and he, to succeed, must be in a position to lay out his work for a series of years in advance. Therefore, while I can not advise your Committee in these matters, and while I realize that it is not proper for me to speak in a personal manner of these things, I desire to urge that before going further with the work on this station, you become thoroughly convinced that you have a man in the position of superintendent who is capable in every way of conducting the same to the best advantage of all concerned. There are certainly many men who are able to fill the position creditably, and I consider it a very poor idea to spend time experimenting with men whose business it should be to experiment with crops.

Respectfully submitted,

W. FRANK CROWLEY,
Superintendent.

ROCKY FORD, COLORADO,
NOVEMBER 30, 1897.

REPORT OF THE RAINBELT EXPERIMENT STATION.

To the Executive Committee of The State Board of Agriculture:

Gentlemen—I herewith present the Fourth Annual Report of the Rainbelt Experiment Station:

The snow which fell in March left the ground with considerable moisture at the beginning of spring work. The work of planting spring crops was begun March 29th and continued until June 5th, at intervals, as the ground was prepared for seed.

No severe storms occurred this season. The rain came mainly in gentle showers, so that but little water ran off. The rainfall during the growing season was .69 inch less than in the same period of 1896, but the snow of March probably more than made up for the difference in rainfall during the six months following. Below is a table which may give some idea of the weather during the growing season.

Month.	Maximum Temperature.	Mean Maximum Temperature.	Minimum Temperature.	Mean Minimum Temperature.	Mean Daily Temperature.	Maximum Daily Range.	Mean Relative Humidity.	Precipitation in Inches.	No. of Rainy Days.	Prevailing Wind.	Per Ct. of Sunshine.
April ...	81.8	62.0	26.0	34.0	48.0	43.8	69%	1.20	8	N.W.	61
May	92.2	76.8	37.0	47.1	62.0	44.0	76%	1.44	5	S. E.	42
June	97.6	78.0	43.0	53.3	65.6	43.0	75%	2.22	10	S. E.	50
July	102.6	89.8	47.6	58.3	74.1	41.0	54%	4.19	5	S.	69
Aug. ...	96.0	83.2	51.0	56.6	69.9	39.0	67%	3.24	6	S. E.	66
Sept. ...	96.0	84.2	37.2	53.7	69.0	43.0	54%	.92	2	S.	76

Total precipitation, 14.21 inches.

The object of the work this year was mainly to test varieties. All hoed crops and trees were cultivated after each rain, when the time between rains permitted, and the ground was in condition for cultivation.

FARM CROPS.

Fall Wheat—Thirty-six varieties of fall wheat were planted in small plats. These included 12 Russian varieties, 10 from the Kansas State Agricultural College, 9 from William Henry Maule, of Philadelphia, and 3 from John A. Salzer; also one-half acre plat each of Turkey and Mediterranean wheat were sown, the seed being obtained from Oakley, Kansas. The following table gives the yield of a few which did the best:

Zimmerman, (in row)	3.97 bu. per acre
Tasmanian Red, (in row)	4.00 bu. per acre
Turkey, (in row)	4.13 bu. per acre
Mediterranean, (in row)	2.07 bu. per acre
Turkey, (broadcasted)	4.87 bu. per acre
Mediterranean, (broadcasted)	4.15 bu. per acre

The other varieties ripened unevenly, producing some very good samples of wheat. All the small plats were in rows 26 inches apart and were cultivated three times during the period of growth.

Spring Wheat—Twenty-six varieties were planted. Thirteen of these came from Brandon, Manitoba, 4 from Montana, and the others from seedsmen. All were planted the same day in rows 26 inches apart and were cultivated three times during growth. The following varieties are the only ones which yielded more than two bushels per acre: Club, 2.28 bu.; Sutherlin, 2.75 bu.; and Ladoga, 2.16 bu.

The yield from seed grown under irrigation was compared with the yield of seed grown by dry farming. Samples of Ladoga wheat were obtained from Montana and Brandon, Manitoba, and sown side by side. The seed grown by irrigation produced 2.16 bu. per acre while that grown by dry farming yielded 1.95 bu. per acre.

Spiltz—A small plat of Spiltz was sown by the side of the spring wheat plats and treated the same way. It produced 2.28 bu. per acre.

Oats—Thirty-six varieties of oats were sown in rows 26 inches apart. Eleven of these were from Manitoba, 4 from Montana, 9 grown at this station last year, and the remainder obtained from seedsmen. Only a few of the earliest varieties ripened evenly so that all the seed could be saved. Of these, the Black Russian yielded 5.62 bu.; Belgian, 3.66 bu.; Red Georgia, 3.66 bu., and Mortgage Lifter, 3.13 bu. per acre.

Barley—Small plats of each of twenty varieties were planted. Ten varieties were from Manitoba, four from Montana, and the remainder from seedsmen. The varieties yielding more than two bushels per acre were: Odessa, 2.75 bu.; Mansury, 2.20 bu.; and Success, 3.25 bu. Unevenness in ripening prevented accurate estimates of the yield of others.

Rye—Four varieties were planted. None yielded more than the seed planted except Colorado Giant Spring Rye which yielded 2.66 bu. per acre broadcasted and 3.77 bu. per acre cultivated.

All small grain was injured by a drouth which occurred when many varieties were in bloom. This was especially true of barley and spring wheat.

Peas and Wheat for Hay—One acre was plowed four inches deep and seeded to Canada Field Peas and wheat. One-half bushel of each was broadcasted and covered with the disc harrow. A good stand came up but all soon died.

Millet—Eleven varieties of millet were planted May 26th on ground which was plowed the first week in May and thoroughly harrowed after each rain. The following table gives the yields of hay:

	Date of Planting.	Date of Cutting.	Yield Per Acre in Pounds.
Hirse	May 26	August 26	2,240
Dakota Seed	May 26	August 26	2,310
California	May 26	August 26	3,130
Hog	May 26	August 12	2,010
Golden Wonder	May 26	August 12	1,790
Manitoba	May 26	August 12	1,810
Early Harvest	May 26	August 12	2,050
Japanese	May 26	August 16	2,210
German	May 26	August 16	2,290
Hungarian	May 26	August 16	3,190
Common	May 26	August 16	3,090

Hirse, Hog, and Manitoba appeared to be very much alike. California, Dakota, Japanese, and Common closely resemble one another.

Broom Corn—Nine varieties were planted. All dwarf and early varieties were failures. Standard varieties, as Tennessee and Missouri Evergreen, produced fair yields of brush of good quality.

Sorghum for Fodder—Test plats were planted to Early Minnesota cane, Early Amber cane, Early Orange cane, White Kaffir corn, Red Kaffir corn, Yellow Milo Maize, Brown Durra, Black Rice corn, African Millet, and Jerusalem corn. The stand was so uneven upon the different plats that no fair estimate of relative yields could be made. All did well where the stand was good.

Sown Sorghum—One acre of sod was sown to Early Amber cane at the rate of 15 lbs. per acre. Also four acres of old ground were sown, using the same amount of seed per acre. The sod ground produced at the rate of 5,600 lbs. of fodder per acre while the yield on the old ground was 4,560 lbs. per acre.

Sorghum in Cultivated Rows—Four acres of Early Amber cane were planted with the planter drill June 5th. The yield of fodder, weighed November 11th, was 6,000 lbs. per acre.

Non-Saccharine Sorghum for Grain—Small plats of Kaffir corn No. 39, Brown Durra, and Jerusalem corn

were planted in the orchard. All were cut September 19th. Birds had damaged the Jerusalem corn some. The yields of the three varieties were:

Kaffir corn, No. 39........	3,473 lbs. of heads per acre
Jerusalem corn...........	3,030 lbs. of heads per acre
Brown Durra.............	3,397 lbs. of heads per acre

Birds molest Brown Durra but very little. Two acres of Brown Durra were planted in the main field. It yielded 1,876 pounds of heads per acre. Common seed was used in the field test, while the seed used on the small plats was from selected home-grown heads.

Fodder Corn—Seven varieties of Indian corn were planted May 15th, for fodder. None produced seed. The yields of fodder were as given in the table following:

Red Cob Ensilage..............	2,268 pounds per acre
Evergreen Sweet Fodder........	720 pounds per acre
Southern Ensilage.............	2,070 pounds per acre
Giant Fodder..................	2,160 pounds per acre
Superior	2,052 pounds per acre
Elephant	1,494 pounds per acre
Earliest Ripe.................	2,538 pounds per acre

Grasses—Forty-five varieties of hay and pasture plants were tried. These included twenty-six varieties of grasses and two varieties of Salt Bush from Australia, twelve varieties of clover, Bromus inermis, and Johnson grass. They were planted upon ground which had been plowed early and specially prepared. At this time, alfalfa and Johnson grass are the only plants which can be seen. Very few of the grasses germinated and others which did soon died.

Cow Peas—Five varieties were planted. All matured seed as follows:

Black, (from Plant Seed Co., St. Louis, Mo.).......	4.8 bu. per acre
Whip-poor Will, (from Plant Seed Co., St. Louis, Mo.)	3.0 bu. per acre
Clay, (from Plant Seed Co., St. Louis, Mo)........	A few pods
Black-eyed, (from Plant Seed Co., St. Louis, Mo.)..	A few pods
Black-eyed, (Home-grown seed)..................	9.9 bu. per acre
Speckled, (Barteldes & Co.)......................	1.8 bu. per acre

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Idaho Peas—A small plat was planted to Idaho Peas. Only a few grew, but the plants made a good growth and were loaded with fruit.

Canada Field Peas—Twelve Varieties of Canada Field Peas were grown. Seven varieties were obtained from Brandon, Manitoba. All grew well, some of the vines being five feet high and full of pods. None have been threshed.

Sand Vetch—A short row of Sand Vetch was planted. It is still green and covers the ground a foot on each side of the rows.

Lupins—Three varieties were planted but were eaten by the grasshoppers as soon as they came up.

Navy Beans—A small plat of Navy beans was planted. They produced a small yield of beans of poor quality.

Field Corn—Forty-eight varieties of corn were planted on high land upon which no other land drained. The ground was plowed the middle of April and harrowed several times, besides being packed with a disc harrow. The corn was planted the 15th and 17th of May. It was much damaged by squirrels so that all varieties showed poor stands. The yields of the varieties are given without apology, as all suffered as fields of corn are liable to suffer in this region. The following table gives the yields of the different varieties:

Variety of Field Corn.	Yield per Acre in Bushels.
Snowflake White	7.7
Pearl White	10.3
Mercer	18.67
Longfellow	19.10
Minnesota White	19.28
Minnesota King	11.93
Drought Register	9.85
Iowa Gold Mine	9.91
Iowa Silver Mine	11.57
Negro Equality	3.77
Rustler	16.71
Sanford's Early	22.04

Variety of Field Corn.	Yield per Acre in Bushels.
Great Long White Flint	7.71
Eclipse	7.34
Improved Leaming	6.61
Earliest Ripe Fodder	2.20
New Leaming	9.95
Queen of the Field, (Home-grown)	12.37
Queen of the Field, (Vaughan)	3.40
Murdocks' 90-day Yellow	10.60
Champion White Pearl	8.87
Extra Early Huron	9.25
Angel of Midnight	7.45
Golden Beauty	9.18
Early Huron	8.49
Houghton's Silver White	11.83
South Dakota Flint	6.04
Brazilian Flour	1.28
North Dakota Flint	8.84
Swadley	9.13
Star Leaming	6.94
Early Eclipse, Yellow	1.48
King Philip	6.55
Squaw Flint	7.84
Queen of the North	5.59
Canada Yellow Dent	5.71
White Cap Yellow Dent	6.49
Will's Gehu, (Home-grown seed)	6.94
Will's Gehu, (Vaughan)	6.55
Waushakum	6.94
Wisconsin Early White	2.44
Colorado White	2.05
Early Yellow Rose	.51
White Australian	9.13
Pride of the North, (Salzer)	4.88
Dakota Dent	6.04
White Kansas King	4.05
Parson's White	8.23

HORTICULTURE.

Trees—All the apple, cherry, and plum trees have made an extra large growth. The twenty apple trees set out in May all lived. Ten of the fifteen plum trees set out lived. Two ash trees died during the summer. All

other forest trees have grown well. The Rocky Mountain cherry trees and the gooseberries bore heavily, and the standard cherry trees bore some fruit. The raspberries have held their own and increased by suckering so that many can be set out next spring. They bore a few berries this year.

Potatoes—Forty varieties of Irish potatoes, chosen from a long list of those which have proved valuable in other regions, were planted May 12th. Some which show the lowest yields are as good as any, but produced small yields on account of a poor stand. About June 15th, the potato beetles (Meloidæ), of many sizes, began upon the potato vines. Before we could get started to spraying the vines, much of the patch was defoliated. At this time, it was noted that while the vines on each side of Carman No. 1, were very ragged from the work of the beetles, Carman No. 1 was apparently untouched, and there seemed to be very few beetles on the vines of that variety, while the rows on each side were covered with beetles. The potatoes were either sprayed with Paris green and water or sprinkled with a mixture of Paris green and lime every few days, or as often as the beetles appeared in numbers. Below is a table which gives the yields of varieties tested:

Variety of Potatoes.	Marketable Tubers. Bushels Per Acre.	Small Tubers. Bushels Per Acre.	Total. Bushels Per Acre.
Early Thoroughbred	37.80	10.20	48.00
Irish Daisy, (Vaughan)	18.50	19.50	38.00
Carman No. 1	27.36	21.60	48.96
Early Vaughan	41.31	9.18	50.49
Victor Rose	24.00	17.00	41.00
Beauty of Beauties	45.00	12.00	57.00
Ajax	17.55	12.89	30.44
Early Six Weeks, (Barteldes)	35.61	10.84	46.45
Maggie Murphy	25.26	7.26	32.52
Carman No. 3	49.80	9.24	59.04
Early Kansas	6.66	1.34	8.00

	Marketable Tubers. Bushels	Small Tubers. Bushels	Total. Bushels
Early Freeman	14.34	7.33	21.67
Boston Red	28.50	9.75	38.25
Early Ohio	40.00	5.60	45.60
Early Six Weeks, (Salzer)	25.34	7.66	33.00
Bliss' Triumph, or Stray Beauty	17.00	22.00	39.00
King of the Earliest	15.32	5.25	20.57
American Wonder	17.28	9.60	26.88
Harvest King	35.52	9.60	45.12
World's Fair	13.76	8.52	22.28
Champion of the World	18.67	6.00	24.67
Ironclad	20.00	12.33	32.33
Good Times	27.34	14.00	41.34
Hundredfold	23.00	11.67	34.67
Early Beauty of Hebron	14.08	5.74	19.82
Irish Daisy, (Salzer)	16.00	14.67	30.67
New York Early Rose	31.20	6.96	38.16
Snowflake	38.21	18.61	56.82
Crown Jewel	24.00	17.50	41.50
Lightning Express	17.60	10.40	28.00
Peerless	5.79	10.35	16.14
Early Fortune	52.56	9.69	62.25
Quick Crop	19.64	3.82	23.46
Early Minnesota	36.93	9.23	46.16
Early Montana	28.40	8.00	36.40
White Star	10.90	9.84	20.74
Extra Early Ohio	29.21	7.30	36.51
Acme	23.00	5.50	28.50
Burbank's Seedling	12.48	9.60	22.08
New Burbank's Seedling	32.00	10.00	42.00

Sweet Potatoes—Seven plats, each consisting of one row four rods long, were planted to sweet potatoes with the following results:

Red Nansemond	43.80 bu. per acre
Black Spanish	66.75 bu. per acre
Southern Queen	60.33 bu. per acre

Yellow Nansemond	43.50 bu. per acre
Yellow Jersey	66.00 bu. per acre
Early Golden, Plat 1	90.75 bu. per acre
Early Golden, Plat 2	187.17 bu. per acre

One specimen of Early Golden weighed 4.67 lbs. The roots of the plant on which it grew were traced seven feet horizontally, and one was traced six feet and five inches deep.

Sugar Beets and Mangel Wurzels—Twelve varieties were planted. None grew.

Pumpkins—Five varieties of pumpkins were planted. Kentucký Field, Cashaw, and Tennessee Sweet Potato gave fair yields. Japanese Pie and Sugar pumpkins produced but a few fruits.

Squashes—Twenty-five varieties were planted May 13th. The bugs were picked off from them twice a week until the middle of July. After this they were left to see if they would withstand the ravages of the bugs. This was done because up to that time we had found no bugs upon Delicata, a late squash which came from Northrup, King & Co., Minneapolis, Minn. Only eight varieties matured fruit. These were Golden Summer Crookneck, Patty Pan, White Bush, Early Yellow Bush, Der Wing, White Pineapple, Brazilian Sugar, and Delicata. All these bore good crops. No vines of Delicata were killed by bugs, but we saw some bugs on them late in the summer.

Watermelons—Eight varieties of watermelons were planted. Ice Cream, Gypsy, Kolb's Gem, Cuban Queen, and Golden Rind gave fair yields of melons. Fourth of July made a large yield and Salzer's Earliest a small yield of extra quality.

Stock Melons—Eight hills of stock melons were planted eight feet apart. At gathering time the vines had spread over eight square rods, and 2,000 pounds of melons were picked from them.

Muskmelons—Seven varieties of muskmelons were planted. All made fair yields.

Mangoes—A few hills of mangoes were planted. The fruit nearly covered the ground near the hill.

Cucumbers—Six varieties of cucumbers were planted, including Salzer's Earliest of All, Early White Spine, Early Cluster, Early Frame, Long Green Turkey, and Maule's Improved Long Green. All bore well. Salzer's Earliest of All and Maule's Improved Long Green were especially productive.

Sunflowers—Three varieties were planted, Black Giant, White Beauty, and Mammoth Russian. No estimate of the yield has been made, but all gave good yields.

Chufas—A small package of Chufas was planted in the garden. They grew well, and now there is a layer of Chufas almost solid under each bunch of tops. Some bunches of grassy tops are ten inches in diameter, all having grown from one seed.

Peanuts—Four varieties of peanuts were planted. Early Virginia, Mammoth Virginia, Root Hog, and Spanish all produced seed of good quality.

Radishes and Lettuce—Both did well. Lettuce planted in the fall as well as that which was self-sown from seed grown in the garden last year did well. Garden beets and onions failed to germinate.

Beans—Thirty varieties of garden beans were planted. The first green beans were picked from Earliest Wax, August 5th. The last picking of green beans was from Henderson's Bush Lima, October 20th. The varieties which bore the best were Salzer's Golden Wax, Earliest Wax, Six Weeks, and Yellow Six Weeks.

Peas—Twenty-two varieties of garden peas were planted. Some varieties which were tried last year were tried on a larger scale this year. The peas were all planted May 12th. Some varieties occupied only a few feet of row, so the yields given in the table below are to show variations in amounts of shelled peas as compared to pods. The table will give some information as to results obtained:

Varieties of Peas.	Amount in Pod in Pints.	Per Cent. Shelled Peas.	Date of Picking.
American Wonder	3	30	June 28
Salzer's Earliest and Best	7¾	31	June 28
First and Best	4	25	June 28
Tom Thumb	1	33	June 28
Rural New Yorker	3¼	31	June 28
Scorcher	9½	30	June 28
Little Gem	4	26	June 28
Alaska	7½	24	June 28
Dwarf Gray Sugar	2½	31	July 8
Early May	4¾	31¼	July 8
Premium Gem	5-16	30	July 8
Yorkshire Hero	⅝	20	July 8
Large White Marrowfat	⅜	8 1-3	July 8
Everbearing	¾	25	July 8
Abundance	9-16	33 1-3	July 8

The following varieties produced fair yields, though not tested for per cent. of peas to the pod: Black-eyed Marrowfat, Pride of the Market, Champion of England, Mammoth Luscious Sugar, Strategem, Summit, and Earliest of All.

Sweet-Corn—Twenty-six varieties of sweet-corn were planted May 11th. The first roasting ears were picked July 26th from Cory, White Cob Cory, Early La Crosse, Telephone, and Early Adams. The last roasting ears were picked Sept. 17th from Country Gentleman and Egyptian. The Early Adams, Shaker's Early Concord, Moore's Early Concord, Early Bonanza, and None Such yielded especially fine ears, both in size and flavor. But there are so many good varieties that it would be hard to choose five for use and prove them better than any others.

The table below gives the date of coming into roasting ears of the several varieties:

Varieties of Sweet-Corn.	Date in Roasting Ears.
White Cob Cory	July 26
Country Gentleman	August 21
First of All, (Salzer)	August 5
Black Mexican	August 4
Cory	July 26
Early Adams	July 26
Egyptian	August 19
Early Minnesota	August 4
Crosby's Early	July 28
Perry's Hybrid	August 5
First of All, (Maule)	July 26
Early Marblehead	July 26
None Such	August 19
Shaker's Early Concord	August 5
Moore's Early Concord	August 9
Early Bonanza	August 14
Northern Pedigree	August 5
Early Sunrise	August 5
Improved Ruby	August 21
Zigzag Evergreen	August 14
Champion	August 5
Early La Crosse	July 26
Telephone	July 26
Minnesota	August 4
Mammoth	August 19
Stowell's Evergreen	August 19

Pop-Corn—Small plats of pop-corn were grown and all of them made fair yields. The following varieties were tried: Queen's Golden, Red Jacket, White Pearl, and White Rice.

WIND-BREAKS AND PROTECTION FOR CROPS.

During the winter of 1896-97, the corn stalks and rows of broom corn left in the field to check the blowing of soil and catch snow showed their usefulness. After each snow storm, the drifts would be from one foot to three feet deep in the strips of stalks left, except in the corn stalks. They soon broke off and were blown away. The guards made of broom corn and sorghum stood well. In one place five rows of Kaffir corn had been left north

of a patch of buffalo grass. Snow drifted so much there during the winter that the effect of the wind-break upon the grass could be seen all summer.

Trees—In May three thousand Russian Mulberry trees were set out in rows across the field. Two rows twelve feet apart and two feet apart in the row were set on the north side of the cultivated forty acres. Twenty rods south of these two more rows were set, and twenty rods south of these a single row was set. These grew well during the season. Also, through the kindness of Prof. Hansen, of Dakota, and Superintendent Bedford, of Brandon, Manitoba, we received nine hundred cuttings of Russian Artemisia. These were planted on the south side of the cultivated land. A good stand started, but the grasshoppers ate nearly all of them so badly that only a few are alive at present.

Of the other trees tried here, the Black Locust and the Green Ash are the most promising trees for use in making permanent wind-breaks and shelter-belts.

The sod wall and board fence wind-break has been extended until it is now twenty-two rods long, but the crops kept us so busy this year that we could not make the tests which we had planned.

CULTIVATION TO PREVENT BLOWING.

During the progress of the spring work, we had all the ground plowed and harrowed except a narrow strip. One day when the wind blew, the dust would rise in dense clouds from the unplowed land, while the same wind would sweep across the harrowed land and not raise enough dust to be noticed. The harrow works the fine soil down below the little clods which protect it from the wind.

EVAPORATION.

From Water—Two pans, each exactly one foot square, were filled with water to a mark every morning at 7 o'clock. Both were measured at 7 p. m. on every sunshiny day and also, upon some days which were

party cloudy. One was placed where the sun could shine upon it, while the other was protected from the sun's rays, but left so that the air could circulate freely about it. The table below gives the differences between the morning and evening measurements of the two pans together with some important meteorological data.

Date.	Relative Humidity.	Mean Temperature.	Sunshine, Per Cent.	Evaporation in Sun.	Evaporation in Shade.
July 12....	57	69.0	100	.469	.219
July 15....	63	71.4	90	.344	.250
July 16....	47	73.5	75	.531	.375
July 17....	80	71.5	50	.563	.125
July 18....	83	66.8	55	.313	.063
July 20....	68	63.1	100	.344	.157
July 21....	54	71.2	85	.344	.219
July 23....	44	76.6	65	.500	.406
July 25....	63	71.0	100	.469	.250
July 26....	39	74.5	65	.500	.375
July 27....	43	74.5	10	.344	.344
July 28....	42	75.6	100	.469	.313
July 29....	35	79.5	100	.563	.406
July 30....	28	78.3	80	.500	.438
July 31....	35	78.5	100	.531	.375
August 1.	42	78.0	35	.469	.375
August 2.	44	74.5	85	.438	.313
August 3.	67	74.5	45	.375	.250
August 5.	72	69.5	90	.300	.100
August 7.	78	70.5	70	.281	.250
August 8.	77	73.3	75	.531	.125
August 10	88	70.5	45	.375	.125
August 11	77	70.6	90	.344	.156
August 12	59	73.4	100	.594	.250
Means .	57.7	72.9	74	.438	.261

Evaporation from soil surface was studied somewhat, but no progress was made except in learning how to arrange the work and carry it on when better opportunity offered. We hope to get more time for this work next year and shall plan with this in view.

Respectfully submitted,

J. E. PAYNE,
Superintendent.

CHEYENNE WELLS, COLORADO,
NOVEMBER 30, 1897.

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THE STATE AGRICULTURAL COLLEGE.

THE AGRICULTURAL EXPERIMENT STATION.

BULLETIN No. 33.

Seepage or Return Waters from Irrigation.

Approved by the Station Council.
ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

JANUARY, 1896.

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SEEPAGE OR RETURN WATERS FROM IRRIGATION.

BY L. G. CARPENTER.

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§ 1. In countries where irrigation is practiced, it is often the case that, though streams may be drained dry by the diversion of the waters into canals, not far below the stream will again be of considerable size, and this without the inflow of visible tributaries.

§ 2. This may become of considerable economic importance, as it already has in the valleys whose measurements are here reported. In the valley of the Poudre, the seepage water is worth, at prices at which sales have already been made, from $300,000 to $500,000 at the least, and the waters of the Platte from two to three million dollars. It is of corresponding importance in the valleys of Clear Creek, St. Vrain, and others. Of such importance al-

ready, it promises, if the deductions of the bulletin are correct, to be of still greater importance in the future and in the development of the State. Certainly it is true that the value of water will steadily increase.

The experience of all irrigation countries shows that their prosperity is largely bound up in the water question—in the certainty of water, in the security of their rights, and the freedom from abuse. They have found themselves often bound by customs and laws, now become fixed, formed as the practice developed gradually. We are in danger of such here, mostly from lack of knowledge of the conditions. This bulletin is a contribution toward a better knowledge of one condition of water supply, which has already given rise to much vexatious litigation, to some harmful divisions, and to some unrest among those affected one way or another.

§ 3. The increase which is found in such rivers is attributed to the inflow from innumerable springs fed and supplied by the water which has been applied in irrigation upon the higher lands. In irrigation, more water is applied than the crop uses. Of that applied, some is used by the crop and stored in its tissues; more is transpired in the process of growth; some is evaporated from the soil; a portion is usually lost by surface run-off; a certain amount passes down into the ground and disappears. This varies in amount and depends upon various conditions. Usually concurrent observations show that this water passes directly downwards, with little or no lateral movement except capillary imbibition, until reaching an impervious stratum, when, filling the interstices, it gradually rises in the subsoil, and passes laterally with a slow movement due to the slope of the water surface which is thus formed. When the passage takes place through the interstices of the soil the movement is very slow, much slower than is ordinarily supposed by those first encountering the subject. It is faster as the material is coarser. Where there are perceptible channels, the movement may be relatively rapid.

§ 4. One of the first effects noted in irrigation where the soil is pervious, is in the filling of the subsoil. The first evidence is found in the gradual rising of the water in the wells which may have been sunk. Throughout the United States where irrigation is practiced, the evidence is ample, for as the application has been made within a single generation, the changes which have ensued from the application of water are within the memory of hosts of living observers. In many places in the Poudre valley, where it was originally forty or fifty feet to water, water now stands from ten to twenty feet from the surface, the subsoil having been filled to a depth of twenty to forty feet.

There is sometimes a lowering during some seasons of the year, due to the lateral passage of the water. The lateral passage

has had the effect in some places of filling in the ground until in some places the water shows on the surface, water-logging or seeping the ground, rendering it unfit for cultivation and capable of growing only sedges, cat-tails, and other water-loving plants. Sometimes on the evaporation of the water, a deposit of alkali is left, rendering the land unfit for cultivation without draining. These effects are found underneath the lines of ditches, so that many companies insert clauses in their contracts for water or for right-of-way freeing the company from liability for damage of such nature. In other cases where contracts do not prevent, it has given rise to suits for damage from such cause.

The water usually first appears near the canal, and progressively further away year by year.

§ 5. The phenomenon has been but little studied. The reason has doubtless been that in most countries irrigation is of such age that there is no record with which to compare the condition now and before irrigation, and the changes due to the construction of canals have been lost in the centuries which have elapsed. There is, however, land in Lombardy which is manifestly seeped and water-logged, and has every appearance of being due to irrigation. Pavia Canal, between Milan and Pavia, built in the early part of this century, has damaged much land. There is loss from the canals themselves, as well as from the water which is applied to the soil.

Wherever the conditions before the construction of canals are within the range of memory, the fact has been observed to a greater or less extent.

Year by year the effect is found farther and farther away from the canal, or from the irrigated locality, as the case may be. In course of time, the waters which are percolating through the subsoil reach the thalweg or the depression of a "draw," or a river, and increase the waters passing therein.

It, therefore, happens that the depressions or draws, which in Colorado are usually dry before irrigation is practiced, contain living streams after irrigation has been carried on for some time. While the Poudre river varies during the year from a maximum of 3,000 to 5,000 cubic feet per second to a minimum of 50 to 100 cubic feet per second, or may vary by forty to eighty times the minimun flow, and other streams correspondingly, these seepage waters will not often vary twice their minimum flow. In consequence the water rights in the seepage channels are usually considered more valuable than those in the river waters.

The particular places at which the waters come to the surface will generally be determined by the nearness of the underlying rock. Frequently the water shows in a particular locality, so that there is a

localized gathering area. There may be several on some of the channels, so that different seepage ditches may be supplied.

§ 6. The present measures which are reported, include measurements made on the Cache a la Poudre river and on the South Platte, in Colorado. Most of the measurements have been made on the former, and have been for the object of determining the amount of the increase in the stream; the relation between the increase and the amount of water applied; between the increase and the area irrigated; and to collect data which should give the means of studying these facts and other phenomena of the return of the waters. The measures on the Platte have been for the same purpose and in connection with the office of the State Engineer of Colorado. To a greater degree, the measures on the Platte were taken because of the light they might show on certain inter-state questions which have, or may arise, and on some points that could not be decided from the Poudre alone.

The present and future importance of the inflow was under estimated. In the course of the measures, the facts determined have led to much wider and more useful application than was anticipated during their progress.

METHODS OF GAGING.

§ 7. The points at which gagings were made are scattered over a distance of 200 miles by the river, without following its meanderings. The distance to be traveled by road is much in excess of this; and the distance is made longer for the reason that the highway does not follow the river, and at many points the headgates and places of gaging are not easily accessible. Some roads cross fields and, until an intimate acquaintance is gained with the river and the special by-ways, time is lost in passing from one point to another.

The first measurement on the Poudre was usually made at the gaging station in the Canon, about 12 miles from the College, at the point indicated on the map [page 16]. On the way the ditches on one side of the river would be examined and the in-takes measured. Where the water exceeded more than a few inches in depth in the smaller channels, or where there was sufficient to measure by the current meter, the meter was used to determine the velocity and thus determine the amount entering the canal. In cases where the canal was small and the in-take at the time of gaging was little, surface floats were often used, and the mean velocity determined in this manner. While not overly accurate, the results obtained can usually be depended upon to within a few per cent., and the absolute error where used is too small to make any appreciable effect in the general result.

In gaging the river at the regular gaging station, which is at a point in the Canon above the headgates of all the principal canals, a tape is stretched across the river between points on the masonry side walls and the depth of the water at each one-foot or two-foot interval measured throughout the entire width, which is very nearly 100 feet. Then observations were taken with the current meter, usually at two-foot intervals, sometimes at less, across the stream. As most of these gagings were made at a time of low water in the spring, or low water in the fall, the meter has been held by hand and the gager has waded the stream. At other points on the river where gagings were made the method has been essentially the same, although the cross-sections have not been as favorable as at the gaging station. It is not thought, however, that any material error has crept in from these sources. In the notes on the measurements some individual sources of error are noted.

DESCRIPTION OF THE POUDRE VALLEY, IN WHICH THE MEASUREMENTS WERE TAKEN.

§ 8. The measurements have been made on the Cache a la Poudre river and also on the South Platte. The "Poudre," as it is called, is the river which drains the valley in which the State Agricultural College is located, and is, therefore, the most easy of access for the purpose of this and similar investigations. It has the additional advantage of being one of the largest irrigation streams in the State, and one which has been the best used for irrigation purposes, and where irrigation has been carried on as completely and successfully as in any part of the United States. There is in addition as large a body of land irrigated in one tract as anywhere in the United States. The phenomena observed are, therefore, found under conditions of irrigation on a large scale. They are of great economic importance to this valley, and may be expected to hold true of other valleys under similar conditions, and where irrigation has been practiced as long as it has here.

The map in the inset [page 16] is intended to give an understanding of the conditions which may affect the return waters in this valley. The gaging station is indicated near the left of the map, below the junction of the north Poudre with the main stream. The only canal above this point which needs consideration is the North Poudre canal, shown on the map, irrigating some 4,000 acres, principally in the valley of the Box Elder.

The main trend of the valley is to the southeast. Near the stream the land is low, the bottom land varying in width from one-half to two miles. These bottoms have been occupied in times past by the bed of the stream, which is subject to shifting at times of high water. With the decrease of floods, and with the use of water for irrigation, the changes are less.

As we pass out of the first bottoms, we reach successively two or three terraces, or mesas, which are generally sandier and stretch back for varying distances. On the north side of the stream the watershed extends many miles, and the streams here indicated as Dry creek, Box Elder creek, Lone Tree creek, and several smaller channels, are simply ravines or depressions which at times after storms are filled with water and may become at such periods raging torrents. Ordinarily their beds are sharply marked and have a clear tributary country; they are entirely dry, giving almost no indication whatever of water. After their channels cross the lines of the canals and enter the irrigated country, these streams begin to carry running water.

The lines of the canals, which follow approximately contour lines, indicate by their bends the general character of the country and the slope. On the north side of the river the land, as a whole, is more uniform than on the south side. Nearly all the irrigation is, therefore, confined to the north side of the river; the exception being in the region near Fort Collins, and a little space near Greeley. Between the two there is a rougher and more broken country on the south side of the stream, not easily reached by canals from the Poudre.

On the south side, the divide which separates the Poudre from the Big Thompson is but a few miles from the main river, and as we reach range sixty-eight, the location of the divide is indicated closely by the ditch which takes from the stream to the south. Some of the waste of this canal passes into the Poudre river. To the west, the drainage on the south side, even the mountain drainage, does not flow into the Poudre to any great extent, the lateral valleys being nearly all tributary to the stream to the south.

The foothills are near the western portion of range sixty-nine, following a line a little east of south. The first ranges, generally known as hogbacks, are formed of gray sandstone, and very shortly afterward the granite is met with, forming the foothills of the main Rockies. The sandstone appears in ridges, and even on the plains for miles the same general appearance may be seen in the buried ridges which traverse the country from north to south, and made evident on the map by the intermediate valleys, in which flow streams like Dry creek, Box Elder creek, etc., approximately parallel for a long distance and separated by pronounced ridges. These ridges sometimes form natural basins, which have been largely used for storage purposes. As the amount of water there stored affects, to some extent, the amount of return waters, the principal reservoirs in use are indicated on the map.

§ 9. As the length of time that irrigation has been practiced, together with the distance of the land from the river, is an important element in the amount of seepage, a fuller description of the

valley is needed with reference to its irrigation. The crops grown in the valley are principally the cereals, alfalfa, and potatoes. Potatoes have been extensively grown only during the last few years, and the greater part of this crop has been grown near the lower end of the valley. The upper end of the valley is confined almost exclusively to alfalfa and grain, with some market gardens. The distribution of the crops affects the application of the water, both in amount and in time of application. The grains receive water early in the season, and rarely any after July 1. Alfalfa receives from one to three irrigations, commonly two, one often in May. Two will be given, then, and if late water be sufficient, a third in August, after the second cutting; this is by flooding. For potatoes, the ground may be irrigated before plowing. If not, then irrigation will usually be commenced in July or early in August, and is practically over by the end of the first week in September, the active period being confined to five or six weeks. With the crops thus grown, irrigation extends from May to September, with minor quantities applied to orchards and gardens both earlier and later. More water is applied in June than in any other month. Until the development of storage capacity by the construction of reservoirs, the amount of water applied in August was necessarily limited by the stage of the river Since then, more is applied, and this being for potatoes, is largely applied to the section composing the east half of the valley.

§ 10. Of the canals shown on the north side of the river, the Cache a la Poudre No. 2 is the oldest of the large canals, being one of the original Greeley colony canals. The land irrigated under the Cache a la Poudre No. 2 has been almost fully occupied for a number of years. Some of the land near the upper end has become too wet to need water, and the stock representing the water hitherto applied to this land has been sold and the water is now largely applied to land lower down the canal, and largely drains into the Lone Tree creek, which empties into the Platte just below the mouth of the Poudre. The Larimer & Weld comes next in point of time of construction, dating from 1879–81. It is the largest of the ditches, having an appropriation of 720 cubic feet per second, and a capacity still greater for a portion of its length. The amount of land brought under irrigation from this canal has largely increased during the past few years. The Larimer County canal has been still more recently constructed, and waters the country still farther from the river to the extent of something like 16,000 or 20,000 acres. Owing to the later appropriation of this canal, and the low stage of water in the river for some years, this canal has not been able to apply as much water compared with its land as the others mentioned, until within the last few years. Recently, by the development of their system of storage reservoirs, combined with the

construction of a canal bringing water from the watershed of the Laramie river, this canal has been able in 1894 and 1895 to secure an amount of water more nearly comparable with the others.

On the south side of the river the canals are mostly small, and have irrigated essentially the same land and the same amount for a number of years.

The other canals of the river have not changed to any great extent in the amount or the distribution of the land irrigated, for eight or ten years. It will be shown later that there is reason to suppose that the water passes through the ground at a very slow rate. Hence the amount of the land irrigated and the time when brought under cultivation will make some difference with the return waters. It seems probable that the seepage due to much of the land under the Larimer & Weld canal, and from the Larimer County, as well as all from the North Poudre canal, has not yet reached the river.

The point where the weir is placed at the canon is in a granite formation inside the foothills. Within a short distance, the Poudre passes out of the granite and cuts across the upturned edges of sandstones of the Jurassic and Cretaceous periods, and its course from this point until it reaches the Platte is across the slightly upturned edges of the strata, which are mostly shale and some sandstone. In some places these form marked ridges across the country, extending slightly northwest. Their effect will be noticed in the map in the case of the drainage on the north side of the Poudre, where many of these small streams extend to the north for a long distance. The canals show the contours approximately as far up as these go.

CHARACTER OF THE STREAM.

§ 11. The character of the stream is essentially that of all our mountain streams, as its source of water supply is in the snows of the mountains. It is low in the spring, increasing from April to the middle of June, when it reaches its highest stage; then decreasing, reaching its low stage again in September. It remains low during the winter. Its maximum discharge may vary from 3,000 to 5,000 cubic feet per second. Its average winter flow is from 50 to 100 cubic feet per second. Its average flow is shown in the following table, the averages being made from records of from three to twelve years for the different months:

TABLE I.

January	110	cubic feet per second.
February	83	" " " "
March	70	" " " "
April	237	" " " "
May	1,245	" " " "
June	2,017	" " " "
July	1,018	" " " "
August	362	" " " "
September	173	" " " "
October	136	" " " "
November	81	" " " "
December	74	" " " "

CONDITIONS AFFECTING ACCURACY.

§ 12. The stream itself is subject to fluctuations, which, however, are more noticeable at times of high water during the summer than at low water, or at the times at which measurements were made. When the snow is melting rapidly the effect of the daily heat is to increase the quantity of snow melted and thus increase the height of water in the river. This makes a very perceptible daily tide, the hour at which it reaches the gaging station varying according to the stage of the river and the distance from which the water comes. When the water is low, the daily rise is later than when the water is high. With high water the greatest height occurs at from 4 to 6 o'clock in the morning; with a low stage of the river it may not be until toward evening. After the principal snow fields are melted the effect of this daily tide is small, so as scarcely to be perceptible upon the self-registering instruments which are located at the gaging station. At the dates at which gagings have been made for the purpose of this investigation, the tide has been very small, the greatest in August, 1894, and has been neglected. Even if not, inasmuch as the greater portion of the river is taken into the canals before many miles, the quantity of return waters found by the measurements would not be affected thereby. It is of small importance, as the greater quantity of the return waters has been found to be near the lower end of the river.

Errors in gaging might introduce some errors in the results, but the relative values should remain the same. The meters, however, have been rated in still water, and the constants determined often enough to indicate that the constants have been nearly the same. The meter usually used has been the "Lallie Meter," made in Denver, Colo. Sometimes a meter made by Messrs. Buff & Berger, of Boston, Mass., has been used.

The omission occasionally of some of the ditches drawing water from the stream would induce an error, but it is not believed that such an error has been committed.

If a portion of the returns by the various creeks and sloughs were waste water instead of seepage water, the quantity found would

be reduced correspondingly. The amount found in these streams is here given in parenthesis (though not counted), and the effect can be easily seen.

Without having determined the actual origin of the water in every case, it is believed that in no case is any of the water derived from above the ditches.

§ 13. The diagram, Fig. 1, shows graphically the amount of return waters as found in the different measurements. The horizontal distances, or abscissæ, give the distances in miles from the gaging station. The vertical distances, or ordinates, indicate the amount of return waters in cubic feet per second. The vertical lines are drawn at the principal points of measurement. The distances have been measured, not along the curves of the river, but on the map, taking generally a straight course across the bottoms, because it is thought that the amount of inflow will not be increased by the curves of the river, but rather will depend upon the straight course of the river, other things being equal. The different lines indicate the different measurements. It is evident that there is a general agreement between them. There are some marked exceptions, which it is difficult to entirely account for. The small amount of inflow in the first ten miles is noticeable in the eighth and ninth measurements, while in all previous ones it had been considerably greater. A decrease between the seventeenth and twentieth miles is noticed twice, and once between the seventeenth and thirty-second mile. Notwithstanding the minor discrepencies, there is a general agreement, especially during the last portion. It may be seen that the total inflow does not vary much.

Several of the measurements were not carried beyond the Ogilvy ditch, which is several miles from the north of the river, and, therefore, the values found are less than had they been continued to the mouth.

§ 14. Table II. shows the rainfall in connection with the gaging, so as to give the means of judging as to the effect of the rainfall of the previous and the current year upon the amount of inflow. The headings of the columns sufficiently indicate the quantities given. Thus, column 3 gives the amount of rain which fell during the calendar year up to the first of the current month of gaging, and the fifth column is the amount of precipitation during the month and previous to the time of gaging. There does not seem to be any particular connection between the wet and dry seasons and the amount of return waters.

With a high river, the amount of water applied is more than when the river is low, because in the latter case there is stinting of water and much land does not secure enough for the needs of the crops, far less than enough to satisfy the owners; hence, we may

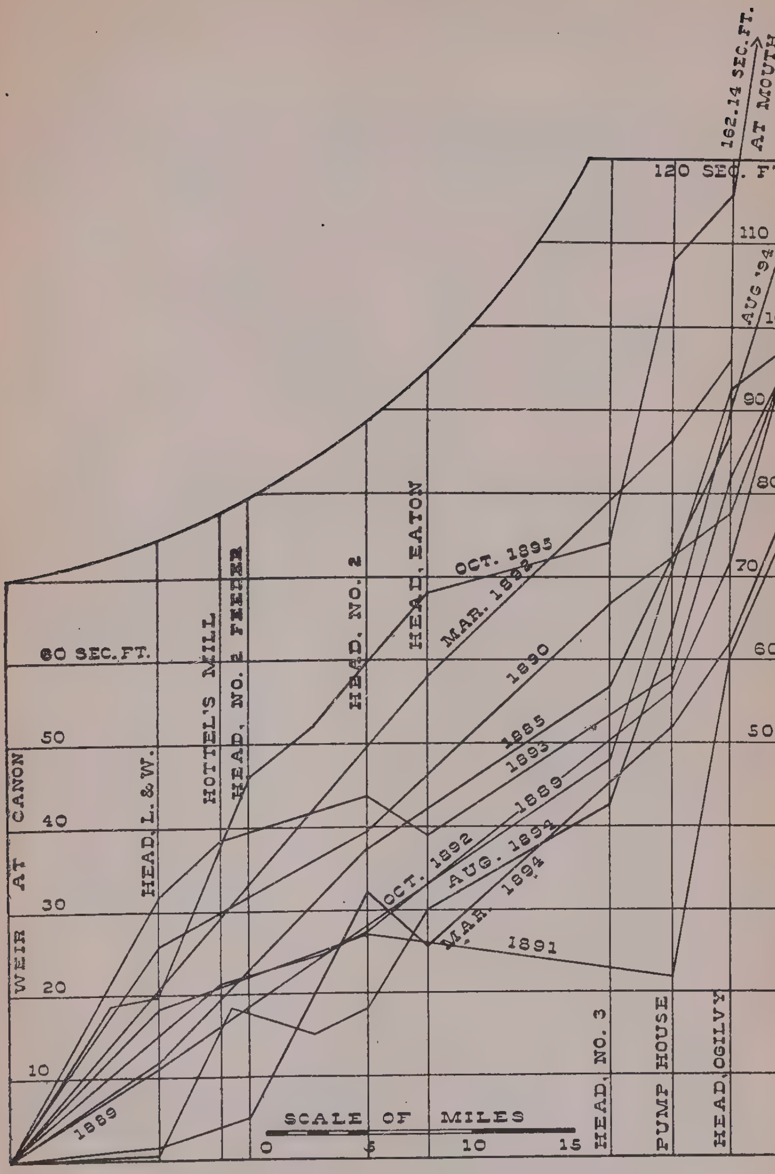

FIG. 1.—Seepage Increase of the Cache a la Poudre River.

expect that the high years of the river will tend to increase the amount of water that is applied, and likewise the amount of water that returns in the form of seepage.

TABLE II.

YEAR.	Rainfall of Previous Calendar Year.	Rainfall to Time of Gaging, first of Month.	Rain During Current Month.	Rain Immediately Before Gaging.	Rain During Gaging.
1884	15.07	....	....	....	....
1885	15.95	....	....	....	....
1889	9.79	10.88	3.16	0.34	.09
1890	14.48	12.42	0.70	0.70-week before gaging	....
1891	13.58	14.43	0.20	0.19-3 weeks " "	0
1892, March	15.69	1.89	1.52	0.83-week " "	0
1892, October	15.69	13.94	0.93	None	0
1893	15.45	6.28	0.16	None	0
1894, March	7.11	0.85	0.67	None	0
1894, August	7.11	9.17	1.53	.08	0
1894, October	....	11.46	T.	None	0
1895	12.36	16.60	1.06	None	0

In the measurement of August, 1894, irrigation was still being carried on quite extensively, especially for potatoes, the most of which are raised toward the lower end of the valley. At this measurement, it is noticed that the total increase is greater than at any previous one, amounting to 118 cubic feet per second. This would seem to show either that a considerable portion of the water returns in a comparatively short time to the river, or that there is some waste which returns directly. During the past few years, there has been an active increase in the use of seepage water for irrigation by the construction of drainage ditches, which in some cases extend back a number of miles. The effect of this is in most cases to cause the water to be applied to the ground nearer the river than where it is cut, and thus the water is developed and hastened in its journey to the river. In some cases the ditches are constructed and deliver the water directly to the river, so that the water returns sooner than it otherwise would. We should expect in consequence a greater development of the inflow during the period immediately succeeding irrigation, and less during the spring following.

NOTES ON THE MEASUREMENTS.

§ 15. The first measurement of the river was made by Mr. E. S. Nettleton, when State Engineer, in 1885, with the aid of Hon. B. S. LaGrange, then Water Commissioner of this district. The measurement was made in October, 1885.

This was at a time when most use of water for irrigation had ceased. A special attempt was made to get all ditches to shut their headgates for the period of the measurement, which had been done very generally by the ditches, so that the amount entering them was only the leakage that passed the gates. No account was made

of the water entering the stream by the small channels, which is given in the later measurements. The assumption was made in this, as in several subsequent measurements, that this water was all seepage water, as, in fact, the investigations of later years have seemed to show.

The second measurement was made in October, 1889, under the direction of Mr. E. S. Nettleton, then Supervising Engineer for the U. S. Geological Survey, and Mr. J. S. Greene, State Engineer.

The inflow determined by this measurement was 99 cubic feet per second in the distance from the gauging station to the mouth of the Poudre. This is a little greater distance than measurement No. 1.

Measurement No. 3, was made in October, 1890, by Mr. L. R. Hope and Mr. E. C. Hawkins, representing J. P. Maxwell, State Engineer, and Col. Nettleton, of the U. S. Department of Agriculture. The total amount of inflow is very nearly the same as in the second measurement.

The fourth measurement, made in the latter part of October, 1891, was made by this Section in co-operation with the State Engineer's measurements of the Platte river, with which the Section also co-operated. During the first day Mr. Trimble assisted and then joined Mr. Hope at Greeley, helping him take the measurement of October 29th, from Greeley to the mouth of the Poudre, and thence going down the Platte, assisting in making these measurements. In this and the subsequent measurements which have been made by this Section, each measurement has shown some features which it has been desirable to avoid, but which it has not been possible to do. In order not to interfere with the use of water for irrigation, in this and the subsequent measurements no attempt was made to regulate the ditches themselves. The time, however, was chosen so that the use of water in any ditch was nearly constant during the few days devoted to the gaging, and the irregularity, if any, is so small as not to affect the results derived from the measurements. There is one measurement, however, to which an exception may be made. This is No. 6, of 1892, during which time the river was constantly affected because of the trading of water between the Larimer & Weld canal and a mill at Fort Collins. Each had some claims to the water, but not to the full amount, hence it became mutually convenient to the two parties to alternate the water, so that the mill used the water during the day and the canal took the water at night for storage. This, therefore, caused fluctuations in the streams at points below the Larimer & Weld headgate, and hence caused some of the discrepancies which are evident in this measurement. Thus, on October 6th, at three o'clock p. m., the river below Strauss's bridge had fifty-four second feet, while the next morning, at 11 o'clock a. m., it had but

twenty-one. This is due to the water entering the canal during the night, and the day water in use by the mill has not yet reached this point. It is not thought that this fluctuation materially affects the indicated inflow at lower points on the river at that date.

The measurements made up to this time indicated that the inflow was approximately the same. Inasmuch as the measurements had been made at only one period of the year, it seemed desirable to know whether or not the amount of return waters was the same at other seasons of the year; hence, beginning with the measurement of 1892, gagings have been made during the spring, when the conditions were favorable, as well as in the fall.

The fifth measurement was made in March, 1892, at a time before the canals had used much water for irrigation, but still when most of them were drawing some water, either for domestic purposes or for irrigating fruit and garden lands. All streams or ditches which contained water were measured and are indicated in this table, as in subsequent ones. In case the streams were bringing water to the river which seemed to be derived from seepage water, thus finding a way to the stream, the amount of the gaging is inclosed in parenthesis, and is not counted in the summation, as it is considered only another way of the water returning to the stream. The source of these waters has not at every gaging been investigated, but, in several cases, and at different times, we have traced these sloughs and creeks to their crossing with the outermost ditches, finding in every case that there is not a stream above the ditch. In some instances the quantity here given may include some waste waters. In general, the amount is insignificant, although in the measurements of August, 1894, there may be some to be thus considered.

In some cases the out-takes of ditches are inclosed in parenthesis. These are cases where the water returned almost immediately to the river. Frequently the measurement was made, and the fact of the water returning was discovered afterwards as we passed down the stream.

In several measurements, as in 1895, it was not possible to complete the gagings without intermission. In these cases the increase was found for each section. In several cases wherever seepage water had been collected in a lateral channel or drainage ditch and was found running into the river, it was measured and noted as a matter of record, and is found inclosed in single parentheses. Where this was caught in another channel, and did not reach the river, it is inclosed in two sets of parentheses. The water is thus found coming from the Big Thompson creek.

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 1—Made by E. S. Nettleton, October 12–15, 1885.

Place of Measurement.	Out-take.	Remainder.	River.	Gain.	No. of Miles.	Gain per Mile.
River at Gaging Station	....	....	127.609	....	....	....
Pleasant Valley & Lake canal	1.75	....	....	....	....	....
Larimer County canal	0.58	....	....	....	....	....
Jackson ditch	0.266	....	....	....	....	....
Little Cache la Poudre ditch	1.00	....	....	....	....	....
Larimer County No. 2 canal	0.534	....	....	....	....	....
New Mercer canal	0.228	....	....	....	....	....
Fort Collins canal	1.14	....	....	....	....	....
Sum	5.498	122.111	....	....	....	....
River, 2⅜ miles above Fort Collins	....	....	133.973	11.862	7.25	1.64
Larimer & Weld canal	1.731	....	....	....	....	....
Pioneer ditch	2.60	....	....	....	....	....
Ames ditch	0.69	....	....	....	....	....
Lake canal	1.248	....	....	....	....	....
Cache la Poudre No. 2	3.216	....	....	....	....	....
Sum	9.485	124.488	....	....	....	....
River at the dam below No. 2	....	....	149.985	25.497	10.10	2.52
The Whitney ditch	1.583	....	....	....	....	....
Greeley No. 3 canal	5.870	....	....	....	....	....
Sum	7.453	142.532	....	....	....	....
River, ¼ mile below No. 3	....	122.908	161.863	19.331	12.25	1.58
Ogilvy ditch	38.955	....	....	....	....	....
River, ⅛ mile below Ogilvy ditch	....	....	153.117	30.209	5.6	5.39
Totals	....	....	....	86.90	35.0	2.48

MEASUREMENT No. 2—Made by L. R. Hope and E. C. Hawkins, under direction of E. S. Nettleton, October 14–17, 1889.

Place of Measurement.	Out-take.	Remainder.	River.	Gain.	No. of Miles.	Gain per Mile.
River at Gaging Station	....	....	68.723	....	....	....
Pleasant Valley & Lake canal	14.781	....	....	....	....	....
Larimer County canal	.818	....	....	....	....	....
Jackson ditch	5.288	....	....	....	....	....
Little Cache la Poudre ditch	6.968	....	....	....	....	....
Taylor and Gill	2.577	....	....	....	....	....
Larimer County No. 2 canal	12.425	....	....	....	....	....
Fort Collins Water Works	.875	....	....	....	....	....
Arthur Irrigating Co. canal	.650	....	....	....	....	....
Larimer & Weld canal	3.040	....	....	....	....	....
Sum	47.422	21.301	....	....	....	....
River, below L. & W. dam	....	....	32.571	11.270	7.25	1.55
Pioneer ditch	1.746	....	....	....	....	....
Josh Ames ditch	1.378	....	....	....	....	....
The Lake canal	1.500	....	....	....	....	....
The Arthur canal	1.497	....	....	....	....	....
Box Elder ditch	6.555	....	....	....	....	....
Cache a Poudre Canal No. 2	55.184	....	....	....	....	....
Sum	67.860	-35.289	....	....	....	....
River, below No. 2 dam	....	....	1.500	36.789	10.10	3.64
Whitney ditch	2.285	....	....	....	....	....
Eaton ditch	.300	....	....	....	....	....
Greeley Canal No. 3	9.835	....	....	....	....	....
Ogilvy ditch	30.098	....	....	....	....	....
Sum	42.518	-41.018	....	....	....	....
River, below Ogilvy dam	....	....	3.480	44.498	17.50	2.54
River, near mouth	....	....	9.887	6.407	3.75	17.09
Totals	157.800	....	....	98.964	38.60	2.56

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 3—Made by L. R. Hope and E. C. Hawkins, October 16–18, 1890.

Place of Measurement.	Outtake.	Inflow.	Remainder.	River.	Gain.	No. of Miles.	Gain per Mile.
River, at Gaging Station				80.776			
Canon ditch	.975						
Larimer County canal	2.849						
Jackson ditch	4.125						
Little Cache la Poudre canal	4.016						
Taylor and Gill ditch	.700						
Fort Collins Water Works	.383						
Larimer & Weld canal	16.401						
Sum	29.449		51.327				
River, below Larimer & Weld dam				77.117	25.79	7.25	3.56
Riddle ditch	.106						
Josh Ames ditch	1.000						
The Lake canal	1.040						
Coy ditch	.973						
Box Elder ditch	5.730						
Cache la Poudre Canal No. 2	79.867						
Sum	88.716		-11.599				
River, below No. 2 canal				2.060	13.66	10.10	1.35
River, above Greeley (Pump House)				19.308	17.25	15.0	1.15
River, at Ogilvy ditch				40.180	20.87	2.00	10.43
Ogilvy ditch	36.675						
River, near mouth				32.729	23.22	4. (?)	5.80
Totals					100.79	38.35	2.63

MEASUREMENT No. 4—Made by L. G. Carpenter and R. E. Trimble, October 28, and by L. G. Carpenter and J. D. Stannard, October 29–30, 1891.

Place of Measurement.	Outtake.	Inflow.	Remainder.	River.	Gain.	No. of Miles.	Gain per Mile.
River at Gaging Station				97.58			
Canon ditch	.03						
Pleasant Valley & Lake canal	6.99						
Jackson ditch	0						
Little Cache la Poudre ditch	5.21						
Taylor and Gill ditch	2.16						
Larimer County canal	1.00						
New Mercer canal	0						
Fort Collins Water Works	0.30						
Larimer County No. 2 canal	.64						
Arthur ditch	1.82						
Larimer & Weld canal	43.30						
Sum	61.45		36.13				
River, below L. & W. canal				54.39	18.26	7.25	2.52
Pioneer ditch	0.0						
Josh Ames ditch	.50						
The Lake canal	.24						
Coy ditch	1.60						
Box Elder ditch	3.78						
Cache la Poudre No. 2 canal	.50						
Sum	6.62		47.77				
River, at head of No. 2				56.48	8.71	10.10	0.86
Whitney ditch	0.0						
Eaton ditch	1.42						
Jones ditch	(8.126)						
Greeley No. 3 canal	32.24						
Boyd and Freeman ditch	2.42						
Sum	36.08	0	11.69				
River, near Pump House				15.3	—5.1	15.0	
Poudre below Greeley				53.56	38.26	2.1	2.24
Ogilvy ditch	18.12						
Waste		5.88					
River, near mouth				60.72	19.40	4.25	4.56
Totals					84.63	38.7	2.19

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 5—Made by L. G. Carpenter and J. D. Stannard, March 10, and by L. G. Carpenter and F. DeVotie, March 11–12, 1892.

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
	MARCH 10.						
....	River at Gaging Station	......	....	65.02	....	....	....
....	Lew Stone creek	......	0.50	......	....	....	....
....	Canon ditch	0	....	......	....	....	....
....	Pleasant Valley canal	4.38	....	......	....	....	....
....	Jackson ditch	2.07	....	......	....	....	....
....	Little Cache la Poudre ditch	1.08	....	......	....	....	....
....	Taylor and Gill ditch	0.59	....	......	....	....	....
....	Fort Collins Water Works	0.22	....	......	....	....	....
....	Larimer County ditch	0	....	......	....	....	....
....	Larimer County No. 2	10.10	....	......	....	....	....
....	New Mercer	0.28	....	......	....	....	....
	MARCH 11.						
....	Larimer & Weld canal	0.72	....	......	....	....	....
....	Pioneer ditch	0	....	......	....	....	....
....	Lake canal	0	....	......	....	....	....
....	Coy ditch	(2.47)	....	......	....	....	....
....	Dry Creek ditch	......	(1.25)	......	....	....	....
....	Ames slough	......	(7.00)	......	....	....	....
....	Cooper slough	......	(2.43)	......	....	....	....
....	Box Elder creek	......	(2.16)	......	....	....	....
....	Spring creek	......	(6.04)	......	....	....	....
....	Box Elder ditch	0.75	....	......	....	....	....
....	Fossil creek	......	(2.72)	......	....	....	....
....	Near Whitney ditch	......	(0.81)	......	....	....	....
	MARCH 12.						
....	Eaton ditch	0.10	....	......	....	....	....
....	Whitney ditch	0	....	......	....	....	....
	Sum	20.29	0.50	......	....	....	....
....	River, near Eaton ditch	......	....	102.54	57.31	20.35	2.82
....	Near Fulton bridge	......	1.15	......	....	....	....
....	Inflow above Briggs	......	(2.25)	......	....	....	....
....	Inflow near Whitney ditch	......	....	......	....	....	....
....	Jones ditch	0	....	......	....	....	....
....	Inflow opposite Jones'	......	(1.35)	......	....	....	....
....	Inflow near Fletcher ditch	......	(0.75)	......	....	....	....
....	Greeley canal No 3	0	....	......	....	....	....
....	Inflow	......	(0.90)	......	....	....	....
	Sum	......	1.15	......	....	....	....
....	River near Pump house		....	132.75	29.06	12.0	2.42
....	Ogilvy ditch	1.00	....	......	....	....	....
....	River below Ogilvy ditch	......	....	141.49	9.74	2.50	3.89
	Totals	......	....	......	96.11	34.85	2.76

MEASUREMENT No 6—Made by R. E. Trimble and J. D. Stannard, October 5–8, 1892.

	OCTOBER 5.						
1 p. m.	River at Gaging Station	......	....	62.92	....	....	....
....	Canon ditch	.03	....	......	....	....	....
....	Jackson ditch	4.51	....	......	....	....	....
....	Little Cache la Poudre ditch	.18	....	......	....	....	....
....	Taylor and Gill ditch (est.)	6.25	....	......	....	....	....
....	Larimer County ditch	0	....	......	....	....	....
....	New Mercer canal	.35	....	......	....	....	....
....	Fort Collins Water Works	.28	....	......	....	....	....
....	Larimer County No. 2 canal	.36	....	......	....	....	....
	Sum	11.96	....	......	....	....	....
....	River 100 yards above L. & W. canal	......	....	66.33	15.37	7.25	2.12
5:30	Larimer & Weld canal	58.86	....	......	....	....	....

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 6 –(Continued).

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
....	River below L. & W. canal.........	......	....	5.95	....	....	....
	OCTOBER 6.						
....	Pioneer ditch, near Inverness farm	.01	....	......	....	....	....
....	Josh Ames ditch..................	.89	....	......	....	....	....
....	The Lake canal..................	2.00	....	......	....	....	....
....	Coy ditch........................	(.74)	....	......	....	....	....
	Sum	2.90	....	......	....	....	....
Noon.	River, below Lindell Mills.........	......	....	52.56	*.60	3.00	....
....	Dry ditch........................	......	(.95)	......	....	....	....
....	Ames slough.....................	......	(2.56)	......	....	....	....
....	Cooper slough....................	......	(2.63)	......	....	....	....
....	Box Elder creek..................	......	(2.90)	......	....	....	....
....	Spring creek.....................	......	(1.25)	......	....	....	....
....	Box Elder ditch..................	2.14	....	......	....	....	....
	Sum	2.14	....	......	....	....	....
3 p.m.	River, below Strauss bridge........	......	....	53.93	3.51	4.75	0.74
	OCTOBER 7.						
11 a.m.	River below Strauss bridge.........	......	....	21.03	....	....	....
....	Inflow below Strauss bridge.......	......	(.02)	......	....	....	....
....	Cache la Poudre No. 2 canal......	1.93	....	......	....	....	....
	Sum	1.93	....	......	....	....	....
Noon.	River, below No. 2 canal...........	......	....	21.65	2.52	2.40	1.05
....	Fossil creek......................	......	(1.33)	......	....	....	....
....	Whitney ditch....................	2.72	....	......	....	....	....
2 p.m.	River, below Eaton ditch...........	......	....	24.90	5.97	3.00	1.99
....	Jones ditch.......................	.15	....	......	....	....	....
....	Greeley No. 3....................	32.20	....	......	....	....	....
	Sum	32.35	....	......	....	....	....
	OCTOBER 8.						
9 a.m.	River, near Greeley Pump house....	......	....	14.36	21.81	12.00	1.82
....	Ogilvy ditch......................	29.14	....	......	....	....	....
....	River, below Ogilvy dam...........	......	....	2.53	17.31	2.50	6.92
3 p.m.	River at mouth....................	......	....	31.69	29.16	3.75	7.78
	Totals......	......	....	......	101.65	38.65	2.47

* Estimated.

MEASUREMENT No. 7—Made by R. E. Trimble and R. Q. Tenney, November 9–11, 1893.

	NOVEMBER 9.						
....	River at Gaging Station...........	......	....	52.47	....	....	....
....	Canon ditch......................	0.48	....	......	....	....	....
....	Pleasant Valley canal.............	4.69	....	......	....	....	....
....	Larimer County ditch.............	0	....	......	....	....	....
....	Jackson ditch....................	4.83	....	......	....	....	....
....	Little Cache la Poudre ditch......	0.23	....	......	....	....	....
....	Taylor and Gill ditch.............	1.41	....	......	....	....	....
....	New Mercer ditch.................	0	....	......	....	....	....
....	Fort Collins Water Works (est.)..	.60	....	......	....	....	....
....	Larimer County No. 2 canal......	1.87	....	......	....	....	....
....	Arthur Irrigating canal..........	0	....	......	....	....	....
	NOVEMBER 10.						
....	Larimer & Weld canal..........	(0.54)	....	......	....	....	....
....	River below L. & W. canal.........	......	....	69.61	31.25	7.25	4.31
....	Pioneer ditch.....................	0.45	....	......	....	....	....
....	Josh Ames ditch.................	1.39	....	......	....	....	....
....	Lake canal......................	0	....	......	....	....	....
....	Coy ditch........................	2.00	....	......	....	....	....

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 7—(Continued).

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
....	River below Hottel Mill	......	....	72.48	6.71	3.25	2.61
....	No. 2 Feeder	6.80	....	......	....	....	....
....	Spring creek	......	(0.68)	......	....	....	....
....	Ames slough	......	(5.00)	......	....	....	....
....	Cooper slough	......	(1.50)	......	....	....	....
....	Box Elder creek	......	(3.70)	......	....	....	....
....	Box Elder ditch	1.04	....	......	....	....	....
....	Cache la Poudre Irr'g Canal No. 2	60.03	....	......	....	....	....
	NOVEMBER 11.						
....	River below No. 2	......	....	9.84	5.23	6.90	0.76
....	Fossil creek	......	(1.35)	......	....	....	....
....	Whitney ditch	0.08	....	......	....	....	....
....	Eaton ditch	0.	....	......	....	....	....
....	River below Eaton ditch	......	....	4.95	—4.81	3.00	—1.60
....	Jones ditch	0.19	....	......	....	....	....
....	Greeley No. 3 canal	0	....	......	....	....	....
....	Boyd and Freeman ditch	3.65	....	......	....	....	....
....	River north of Pump house	......	....	20.32	19.21	12 00	1.60
....	Ogilvy ditch	0.65	....	......	....	....	....
....	River below Ogilvy dam	......	....	43.26	23.59	2.50	9.44
....	River at the mouth	......	....	60.76	17.50	3.25	5.38
	Totals	......	....	......	98.68	38.15	2.59

MEASUREMENT No. 8—Made by R. E. Trimble and R. Q. Tenney, March 13–15, 1894.

	MARCH 13.						
....	River at Gaging Station	......	....	99.21	....	0	....
....	Canon ditch	0.03	....	......	....	....	....
....	Pleasant Valley & Lake canal	{ (4.70) 12.60	....	......	....	....	....
....	Larimer County canal	0.25	....	......	....	....	....
....	Jackson ditch	6.17	....	......	....	....	....
....	New Mercer canal	0	....	......	....	....	....
....	Fort Collins Water Works	0.60	....	......	....	....	....
....	Little Cache la Poudre canal	0.53	....	......	....	....	....
....	Taylor and Gill ditch	5.22	....	......	....	....	....
....	Chamberlain ditch	(2.00)	....	......	....	....	....
....	Larimer County No. 2 canal	0.57	....	......	....	....	....
....	Arthur Irrigating canal	0	....	......	....	....	....
....	Larimer and Weld canal	25.30	....	......	....	....	....
....	Riddle ditch	0.33	....	......	....	....	....
....	River below L. & W. canal	......	....	49.18	1.57	7.25	0.22
	MARCH 14.						
....	Pioneer ditch	......	....	......	....	....	....
....	Ames ditch	1.28	....	......	....	....	....
....	Lake canal	0.16	....	......	....	....	....
....	Coy ditch	0	....	......	....	....	....
....	No. 2 Feeder	49.70	....	......	....	....	....
....	River below No 2 Feeder	......	....	1.49	3.45	4.45	0.78
....	Spring creek	......	(2.78)	......	....	....	....
....	Ames slough	......	(0.22)	......	....	....	....
....	Cooper slough	......	(1.21)	......	....	....	....
....	Box Elder ditch	0.11	....	......	....	....	....
....	Box Elder creek	......	(0.24)	......	....	....	....
....	No. 2 Feeder, north of Timnath	(23.90)	....	......	....	....	....
	MARCH 15.						
....	Cache la Poudre No. 2 canal	1.43	....	......	....	....	....
....	River below No. 2	......	....	27.17	27.22	5.65	4.82
....	Fossil creek	......	(0.19)	......	....	....	....
....	Eaton ditch	.08	....	......	....	....	....
....	River below Eaton ditch	......	....	20.44	—6.65	3.00	—2.22
....	Jones ditch	0	....	......	....	....	....
....	Greeley No. 3 canal	0.12	....	......	....	....	....
....	Boyd and Freeman ditch	0.12	....	......	....	....	....

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 8—(Continued).

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
....	River near Pump house...	......	....	46.46	26.26	12.00	2.19
....	Greeley drain sewer...............	(1.47)	....	......	....	....	....
....	Ogilvy ditch......................	0	....	......	....	....	....
....	River below Ogilvy dam............	......	....	56.51	10.05	2.50	4.02
....	River at mouth, ⅛ mile above.......	......	....	76.93	20.42	3.25	6.28
....	Totals......	......	....	......	82.32	38.10	....

MEASUREMENT No. 9—Made by R. E. Trimble and John D. Bloomfield, August 20–23, 1894.

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
	AUGUST 20.						
12:35	River at Gaging Station............	......	....	268.07	....	....	....
2:45	Canon ditch........................	0.80	....	......	....	....	....
11:30	Pleasant Valley & Lake canal..	23.63	....	......	....	....	....
3:15	Larimer County ditch............	31.39	....	......	....	....	....
4:15	Jackson ditch.....................	11.17	....	......	....	....	....
10:40	New Mercer canal..	3.42	....	......	....	....	....
....	Fort Collins Water Works........	0.60	....	......	....	....	....
4:40	Little Cache la Poudre canal....	7.87	....	......	....	....	....
4:50	Taylor and Gill ditch.............	4.46	....	......	....	....	....
....	Chamberlain ditch.............. .	4.53	....	......	....	....	....
....	Larimer County No. 2 canal......	0	....	......	....	....	....
....	Arthur Irrigating canal...........	0	....	......	....	....	....
5:40	Larimer & Weld canal..........	27.80	....	......	....	....	....
6:15	River below L. & W. canal......	......	....	153.17	0.77	7.25	0.11
	AUGUST 21.						
9:20	Pioneer ditch......................	0.16	....	......	....	....	....
9:50	Ames ditch.........................	2.56	....	......	....	....	....
10:10	Lake canal.........................	0.13	....	......	....	....	....
10:20	Coy ditch..................	16.30	....	......	....	....	....
11:10	River at Coy's farm................	......	....	(151.61)	17.59	3.50	5.26
11:55	Coy ditch waste	......	0.82	......	....	....	....
12:00	Coy slough	......	(1.70)	......	....	....	....
2:45	Horner supply	6.39	....	......	....	....	....
3:15	Chaffee ditch......................	2.77	....	.....	....	....	....
3:40	Pioneer waste	......	9.51	......	....	....	....
	Horner supply waste...............	......		......	....	....	....
9:15	Spring creek (Aug. 22)....... ...	......	(5.56)	......	....	....	....
4:00	Ames slough.........	......	(0.90)	......	....	....	....
4:30	Emigh drain ditch	(3.00)	....	......	....	....	....
9:50	Cuthbertson (Aug. 22)...........	......	(0.51)	......	....	....	....
....	Cooper slough (into Emigh drain)	......	(0.50)	......	....	....	....
4:45	Box Elder creek..................	......	(2.52)	......	....	....	....
10:15	Box Elder ditch (Aug. 22)	7.93	....	......	....	....	....
5:40	River at Strauss bridge............	......	....	141.52	—3.33	4.20	—0.79
	AUGUST 22.						
11:05	River at Strauss bridge..............	......	....	139.61	....	....	....
12:35	Cache la Poudre No. 2 canal......	74.27	....	......	....	....	....
1:35	River below No. 2....	......	....	68.45	3.12	2.40	1.30
2:45	Fossil creek......................	......	(4.58)	......	....	....	....
3:50	Whitney ditch.....................	19.98	....	......	....	....	....
3:35	Eaton ditch.......................	10.90	....	......	....	....	....
4:00	River below Eaton ditch...........	......	....	49.44	11.86	3.00	3.95
6:40	Jones ditch............	5.28	....	......	....	....	....
	AUGUST 23.						
10:50	Greeley No. 3 canal.....	56.55	....	......	....	...	....
10:25	River below No. 3.....	......	....	0.29	12.68	9.	1.41
12:10	Royd and Freeman ditch..........	3.30	....	......	....	....	....
2:30	River near Pump house............	......	....	18.13	21.14	3 00	7.05
3:15	Greeley drain sewer	(3.51)	....	......	....	....	....
3:50	Ogilvy ditch......................	38.39	....	......	....	....	....
4:15	Camp Bros. river supply.......	1.17	....	......	....	....	....
4:45	Camp Bros. Slough supply......	(2.16)	....	......	....	....	....
4:25	River below C. Bros, river supply	......	....	4.93	26.36	3.00	.79
6:00	River ½ mile above mouth.........	......	....	32.90	27.97	2.75	.17
	Totals	....	....	......	118.16	38.10	3.10

GAGINGS OF THE CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

Measurement No. 10—Made October 9-14, 1895.

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
	November 9.						
....	River at Gaging Station............	......	....	66.47	....	....	....
....	Canon canal......................	.10	....	......	....	....	....
....	Pleasant Valley & Lake canal..	21.23	....	......	....	....	....
....	Inflow from Canon canal.........	......	.13	......	....	....	....
....	Larimer County canal....	0	....	......	....	....	....
....	Jackson ditch....................	0	....	......	....	....	....
....	River 150 yards above Mercer ditch	......	....	63.53	18.75	5.50	3.41
....	New Mercer ditch..................	0	....	......	....	....	....
....	Little Cache la Poudre ditch.....	6.67	....	......	....	....	....
....	Taylor and Gill ditch.............	4.55	....	......	....	....	....
....	Chamberlin ditch..................	......	....	......	....	....	....
....	Larimer County No. 2 canal......	.50	....	......	....	....	....
....	Fort Collins Water Works (est.).	.75	....	......	....	....	....
....	Inflow waste from T. & Gill ditch	......	3.63	......	....	....	....
....	Inflow waste from T. & Gill ditch	......	.93	......	....	....	....
....	Arthur ditch......................	2.88	....	......	....	....	....
....	River above Larimer & Weld.....	......	....	54.10	1.46	1.75	.81
	October 10.						
....	River below Larimer & Weld....	......	....	0.55	....	....	....
....	Pioneer ditch.....................	0.28	....	......	....	....	....
....	Seepage ditch	.....	(0.50)	......	....	....	....
....	Ames ditch...................... .	0.21	....	......	....	....	....
....	Lake canal........................	3.06	....	......	....	....	....
....	City sewer........................	......	....	......	....	....	....
....	College sewer.....................	......	....	......	....	....	....
....	Coy ditch.........................	.01	....	......	....	....	....
....	No. 2 Res. supply canal..........	.18	....	......	....	....	....
....	River below No. 2 Res. Supply canal	......	....	26.44	26.63	4.4	6.05
....	Dry creek.........................	......	(1.71)	......	....	....	....
....	Ames slough......................	......	(0.96)	......	....	....	....
....	Emigh drain.......................	......	((3.68))	......	....	....	....
....	Cooper slough..............	......	((0.53))	......	....	....	....
....	Box Elder creek.......	......	(3.76)	......	....	....	....
....	Spring creek......................	......	(6.12)	......	....	....	....
....	Box Elder ditch..................	0	....	......	....	....	....
....	Seepage ditch from Spring creek.	......	((0.63))	......	....	....	....
....	Side Hill ditch from Spring creek	......	((2.53))	......	....	....	....
....	Ditch from Cooper slough........	......	((1.15))	......	....	....	....
....	River at Strauss bridge...........	......	....	32.53	6.09	4.2	1.45
	October 14.						
....	River at Strauss bridge.	......	....	26.24	....	....	....
....	Cache la Poudre No. 2 canal......	.02	....	......	....	....	....
....	River below Cache la P. No. 2 canal	......	....	33.73	7.51	2.4	3.13
....	Fossil creek......................	......	(7.63)	......	....	....	....
....	Whitney ditch...............	5.72	....	......	....	....	....
....	Eaton canal......................	8.09	....	......	....	....	....
....	River below Eaton canal...........	......	....	26.91	6.99	3.0	2.33
....	Seepage ditch..........	......	(1.34)	......	....	....	....
....	Jones ditch......................	1.39	....	......	....	....	....
....	Greeley No. 3 ditch (Oct. 15)......	13.10	....	......	....	....	....
....	River below Greeley No. 3 ditch....	......	....	19.77	7.35	9.0	.82
	October 15.						
....	Greeley No. 3.....................	.61	....	......	....	....	....
....	River below Greeley No. 3 ditch....	......	....	32.26	....	....	....
....	Waste into No. 3.................	......	((1.86))	......	....	....	....
....	Waste into No. 3...	......	((0.56))	......	....	....	....
....	Boyd and Freeman ditch..........	2.77	....	.... .	....	....	....
....	River at Pump house...............	......	....	62.73	33.85	3.0	11.28
....	Mill Power canal.................	(4.05)	(5.40)	......	....	....	....
....	Ogilvy ditch......................	0	....	......	....	....	....
....	River below Ogilvy dam...........	......	....	70.47	7.74	2.5	3.10
....	Camp ditch.......................	0	....	......	....	....	....
....	River ½ mile above mouth..	......	....	116.84	46.37	3.25	5.05

TABLE III.

SUMMARY OF THE PRECEDING TABLES, SHOWING GAIN IN SEEPAGE OF CACHE A LA POUDRE RIVER.

(In cubic feet per second.)

	1885.	1889.	1890.	1891.	Mar. 1892.	Oct. 1892.	1893.	Mar. 1894.	Aug. 1894.	1895.
Canon to Larimer & Weld canal..	11.9	11.3	25.8	18.3	......	15.4	31.3	1.6	0.8	19.61
Larimer & Weld to No. 2 canal...	25.5	36.8	13.7	8.7	......	12.0	11.9	30.67	17.4	13.6
No. 2 canal to Ogilvy ditch.......	49.5	44.5	38.1	38.3	......	45.1	38.0	29.8	72.0	55.9
Ogilvy ditch to Mouth of Poudre.	......	6.4	23.2	19.4	......	29.2	17.5	20.4	28.0	46.4
Total Gain	86.9	99.0	100.8	84.6	96.1	101.6	98.7	82.3	118.2	164.4

DESCRIPTION OF THE PLATTE.

§ 16. The portion of the Platte river which was subjected to measurement consisted of that portion below the junction of the Poudre river with the Platte, to the State line between Colorado and Nebraska, at the point where the Platte enters the western extension of Nebraska. The country traversed by the Platte has still the main characteristics of that nearer the mountains. From the junction with the Cache a la Poudre, the Platte leaves the general northerly course which it has traveled since leaving the foothills above Denver, bends abruptly eastward and crosses the ridges which run approximately parallel to the mountains. The effect of these ridges in guiding the drainage of the plains is shown by the long lateral channels. On the south these extend nearly parallel to the Platte for 90 miles, extending to the divide between the Platte and Arkansas rivers, east of Colorado Springs. For a portion of the distance, the Box Elder is within a short distance of the Platte, but, confined by these ridges, it does not meet the Platte until the latter cuts through these ridges. These are drainage channels rather than tributaries, for, except in times of freshets or storms, they do not contain water. Near the heads they are living streams. The last drainage channel from the south of any consequence enters the Platte east of Fort Morgan; for the rest of the distance the drainage of the country on the south side is collected by branches of the Republican river.

§ 17. On the north the Platte takes the drainage of the country as far north as Wyoming. The three principal lines of drainage—Lone Tree, Crow, and Lodge Pole creeks—each head near Cheyenne, the first two entering the Platte near Greeley, the last passing nearly eastward for 150 miles, forming the line followed by the main line of the Union Pacific Railway between Julesburg and Cheyenne, and enters the Platte 150 miles farther east, just above Julesburg.

None of these, nor any of the other channels to which the name creek is applied, can be spoken of as tributaries. It is rare

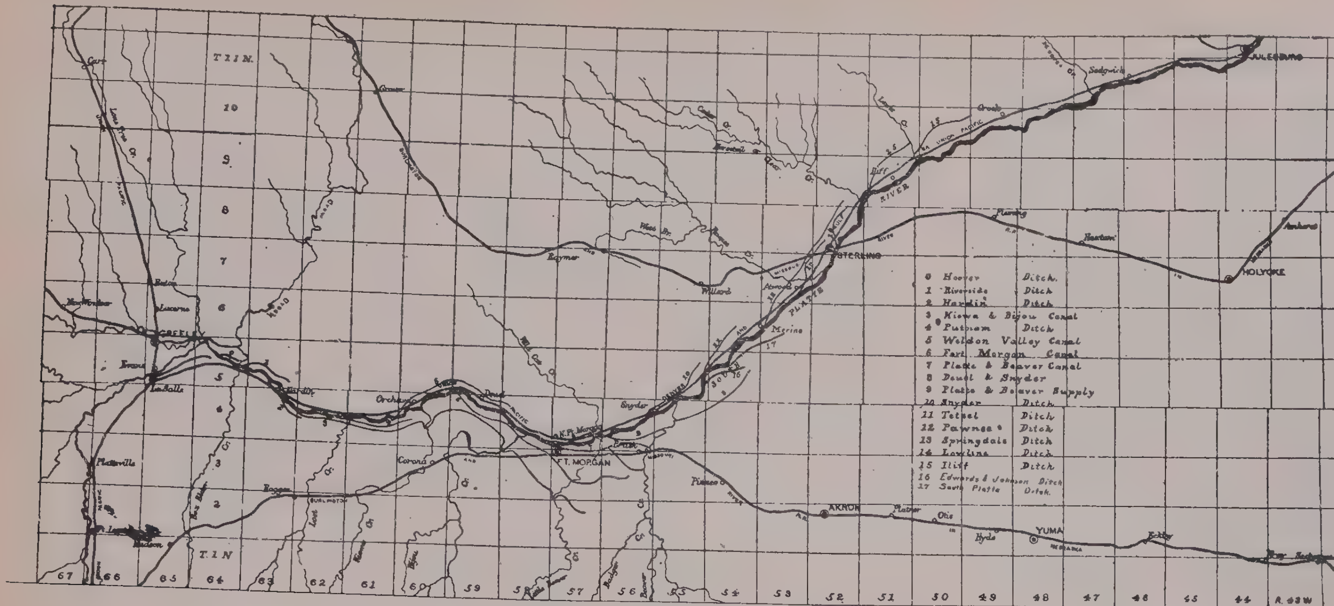

FIG. 3--Map of the South Platte Valley.

that any water reaches the Platte through their channels, the only times being after heavy rains or sudden and violent storms on the higher grounds on either side. In these cases, the plains shed water as a roof, and the channels bring down violent floods, dangerous, it may be, to travelers. The area drained by these channels is great. As in most cases, the channels are confined by ridges of rock, it was thought that there might be some indication of underground increase from these streams, even if no visible surface inflow. Accordingly in 1894 it was tested by measuring the river above and below the points where the creeks debouch into the bottoms, with results given later.

For a portion of the lower course of the stream, it is lined on one or both sides by a strip of sand hills and dunes, molded and blown by the wind, back of which is a country free from sand.

§ 18. The bed of the stream is a bed of sand, of varying fineness—in some places and at some times quicksand—and shifting with the current, which changes from one side to the other. For some miles below the mouth of the Poudre, the stream is in one channel. It is then gradually broken up by sandbars and by small islands into smaller channels, increasing in number. At the State line there were sixteen channels where we measured in 1895. These channels are constantly shifting by bars forming or washing away in the rapid current, so that they change their importance and frequently their position. The general location of the bed seems to be fairly stable. The river requires bridges some 600 to 1,000 feet in length. The slope of the bed of the river averages about eight feet per mile between the mouth of the river and Julesburg, being greater at the upper portion and less at the lower end. When there is much water this fall is sufficient to give the current great velocity, constantly carrying along the sand, depositing, removing and shifting it.

§ 19. The principal ditches along the course of the river are shown on the map (Fig. 3). It will be noted that the area limited by the outermost ditch under irrigation does not cover a wide strip. Many of the ditches are small, some used to irrigate only the bottom lands. Others, like the Fort Morgan, the Weldon Valley, the Platte and Beaver, and Pawnee Canal systems, irrigate considerable areas of excellent land and are almost the only ones passing out of the bottoms.

If the water reaches the river from the land irrigated, it may be expected to drain into the river following the lines of surface drainage, though remaining unseen. It cannot cross the ridges between the channels. As a rule, wherever the facts are known, the ridges are of rock which is higher than the bottoms of the channels. With the system of ditches, there is then some pos-

sibility of separating the drainage of extensive areas of irrigated land from land which receives little or no irrigation.

COMPLICATING CONDITIONS.

§ 20. The bed is almost invariably of sand of unknown depth. In a few places the rock of the ridges cut through by the river shows at the surface. If there is any flow in the sand, it may be expected to be forced to the surface at such places and increase the volume of the stream. Such a place is just above the Bijou creek, above Fort Morgan. And again below the Hardin ditch and above the Corona ditch the bluffs on the south side of the river are prominent, and show evidence of rock outcropping across the river. The sand is porous and has the capacity to hold much water. The results which may be met with in the natural inflow are masked by the effects due to the varying distance to the rock. These may sometimes be more than sufficient to counterbalance the increase from the inflow. This may explain the unusual gains noticed in several places and the losses which are found in certain stretches, even where an area of irrigated land is tributary to that section. The most marked case is at the mouth of Bijou creek. In the measurement of 1894, which was made above and below the Bijou, a gain was looked for in the few miles between the two measurements. The Bijou drains some 1,400 square miles. Besides, there was some water evident on the south side seeping into the river. Nevertheless, a loss was found in 1894, and in 1895 on making another test the gain was so slight that it may be called a loss. In both cases the Platte & Beaver canal was measured several miles from its head, and the loss for the few miles if considered may make a slight gain. But with all allowance possible for this, the gain is slight, or an actual loss which the measurements show. Moreover, at the last point of measurement, there are practically no bottom lands.

§ 21. The methods of irrigation on the lower Platte are somewhat different from those on the Cache a la Poudre, and this may account for the difference in the relative magnitude of the result. The Poudre being a mountain stream, fed almost solely by melting snow, is low in the autumn and late summer. On the Platte the summer flow is small, being reduced both by the usage above and by the avidity of the sands and atmosphere. In the fall, however, the seepage from all the streams nearer the mountains—Clear creek, Boulder creek, St. Vrain, Big Thompson, and Cache a la Poudre—pour the seepage from these channels and the greater part of the flow received from the mountains into the Platte. As a consequence the Platte is higher in the fall and winter. This gives the settlers along the Platte opportunity to irrigate extensively in the fall, and as late as the ditches can well carry water; they thus

each year irrigate their lands. At the time of measurement they were irrigating extensively. It will be noticed in the tables, as in 1895, that the canals are running nearly, if not quite full, though late in the season. This in itself increases the rapidity of flow from the lower ends of the small tubes extending to the river, and is one reason why the increase of water is more than in the case of the Poudre in proportion to the same area irrigated. The use of water at this time when vegetation is not active, also permits the use of water in greater quantities without damage. We have no measures which determine the amount actually used, but from observation and the conditions, it seems probable that water is used in greater quantities than in the Poudre valley.

§ 22. Fig. 4 shows graphically the results of the gagings below the mouth of the Poudre. The distances between the points of measurement are in proportion to the distance between the lines. The amount of gain is indicated by the distance the line is above the base. Hence the steeper the line in any section, the faster is the gain in that section. If the line descends, as it does in some places, it indicates a loss.

§ 23. The tables show the measurements in detail, and give the results of each. The dates and the observers are also given. The distances given are different from the distances given in the report of the State Engineer, but are believed to be here correct. In some cases the distance between the same points in different years is apparently not the same, the reason being that the place of gaging was not quite the same.

In gaging the Platte, the trouble to find accommodations caused considerable interference with the best prosecution of the work. Often after the last gaging of the day a drive of some miles would be necessary, and the river would be taken up at another point the next morning. This did not allow a check on any change the river may have undergone during the night. In 1895 a tent and camp wagon was taken as far as Sterling, and the party camped where night overtook them.

The height of the river was observed both night and morning. It was proved that the change was exceedingly small, amounting, usually, to an increase of about one-fourth inch during the night and a corresponding decrease during the day. A loose block of wood placed at the edge of the water the second night out from Greeley was undisturbed a week later and still just at the edge of the water, indicating a very steady condition of the stream.

The ditches were not disturbed. Where streams are not mentioned in some of the measurements, it is because they were found to be dry.

In 1895 several small ditches near Julesburg were found to be drawing water. Their existence had never been reported to the Water Commissioner, so that they had not been looked for in 1894.

The measurement of March, 1892, was interfered with by snow, which prevented carrying the gaging beyond Fort Morgan.

In 1895 where any of the quantities are enclosed in parentheses, they are not to be taken in the summation. In the case of inflow it was known to be seepage, or in case of out-take it returned immediately to the river.

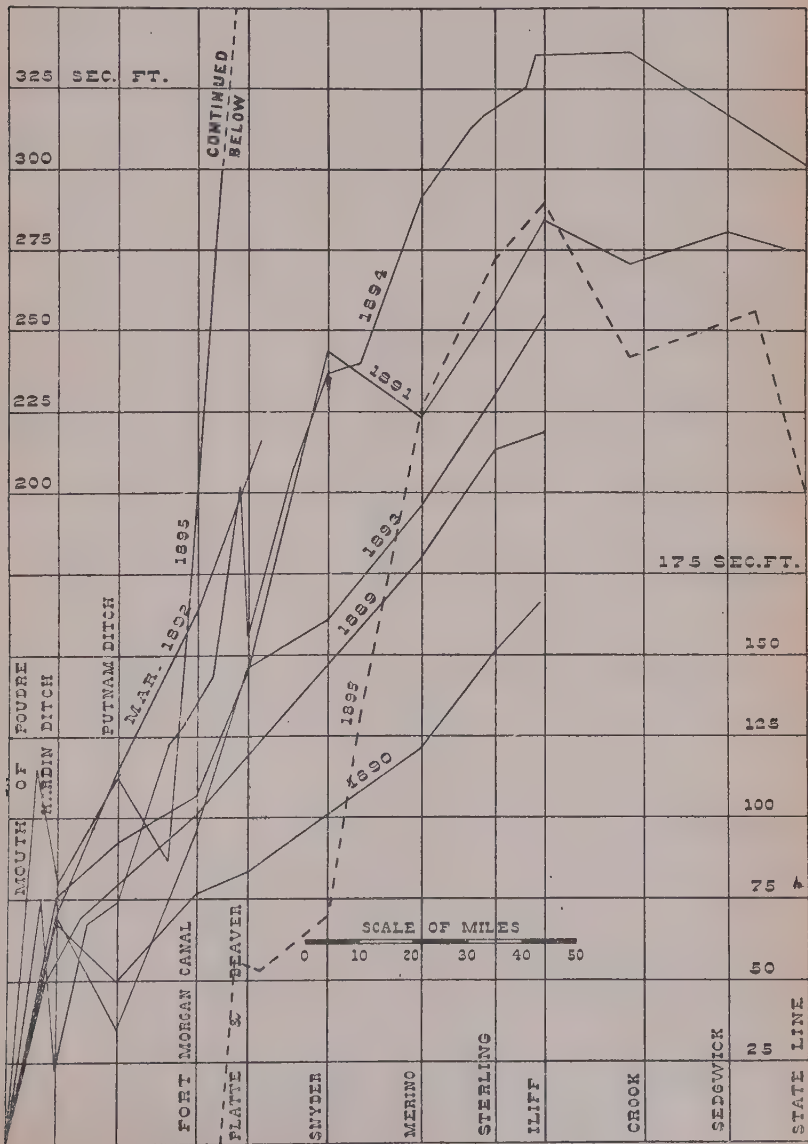

FIG. 4.—Seepage Increase of the South Platte River.

GAGINGS OF THE SOUTH PLATTE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 1—Made by L. R. Hope and E. C. Hawkins, October, 1889.

Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
River at head of Latham ditch	......	....	45.718	....	....	....
Cache a la Poudre river	......	14.830	......	....	....	....
River at Hoover ditch	......	....	120.136	*49.000	6.30	9.46
Hardin ditch	1.005	....	......	....	....	....
River, at head of K. and B. ditch	......	....	139.641	20.51	7.20	2.85
Small ditch (no name)	2.00	....	......	....	....	....
Putnam ditch	30.905	....	......	....	....	....
River at ——	......	....	105.769	....	....	....
Fort Morgan canal	131.932	....	......	....	....	....
River below Fort Morgan canal	......	....	3.625	30.755	19 0	1.62
Bijou creek	......	3.575	......	....	....	....
River at Deuel	......	....	8.310	1.11	12.0	0.09
Deuel and Snyder ditch	3.567	....	......	....	....	....
Platte & Beaver canal	25.023	....	......	....	....	....
Lower Beaver ditch	17.487	....	......	....	....	....
Beaver creek	......	7.000	......	....	....	....
Smith ditch	8.447	....	......	....	....	....
Tetsel ditch	2.340	....	......	....	....	....
South Platte ditch	24.106	....	......	....	....	....
Pawnee ditch	4.367	....	......	....	....	....
River at Merino	......	....	8.481	78.508	30.75	2.55
Schneider ditch	12.609	....	......	....	....	....
Springdale ditch	3.583	....	......	....	....	....
Sterling ditch No. 1	10.076	....	......	....	....	....
Low line ditch	1.796	....	......	....	....	....
Smith and Henderson ditch	6.833	....	......	....	....	....
River at Sterling	......	....	6.378	32.794	13.75	2.39
Sterling ditch No. 2	1.946	....	......	....	....	....
Arnette ditch	8.871	....	......	....	....	....
River near Iliff	......	....	......	4.439	9.25	0.48
Total	......	....	......	217.116	....	....

* Estimated portion seepage from mouth of Poudre river to Hoover ditch.

MEASUREMENT No. 2—Made by L. R. Hope and E. C. Hawkins, October, 1890.

Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
River above Cache a la Poudre river	......	....	98.458	....	....	....
Cache la Poudre river	......	32.729	......	....	....	....
Box Elder creek	......	23.524	......	....	....	....
Hardin ditch	10.279	....	......	....	....	....
River below Hardin ditch	......	....	213.174	68.742	8.0	8.59
Bijou canal	21.424	....	......	....	....	....
Winkle ditch	2.220	....	......	....	....	....
Putnam ditch	6.581	....	......	....	....	....
River below Putnam ditch	......	....	164.881	−18.775	12.25	−1.53
Weldon Valley ditch	31.674	....	......	....	....	....
River 4 miles below Orchard	......	....	156.403	23.196	12.25	1.89
Fort Morgan canal	114.262	....	......	....	....	....
River below Fort Morgan canal	......	....	45.931	3.79	1.5	2.53
Small gulch (no name)	......	7.421	......	....	....	....
Bijou creek (waste from Ft. M. canal)	......	2.028	......	....	....	....
Platte & Beaver canal	36.674	....	......	....	....	....
River below P. & B. canal	......	....	25.215	6.509	11.0	0.59
Platte & Beaver Supply ditch	24.155	....	......	....	....	....
Smith ditch	5.199	....	......	....	....	....

GAGINGS OF THE SOUTH PLATTE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 2—(Continued).

Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
River at Snyder	......	....	12.950	17.089	13.75	1.24
Tetsel ditch	4.250	....	......	....	....	....
South Platte ditch	17.661	....	......	....	....	....
Pawnee ditch	3.881	....	......	....	....	....
River ¼ mile above Merino	......	....	8.444	21.286	18.0	1.18
Schneider ditch	5.063	....	......	....	....	....
Springdale ditch	18.500	....	......	....	....	....
Smith and Henderson ditch	2.640	....	......	....	....	....
River at Sterling	......	....	11.933	29.692	13.75	2.16
Sterling No. 2 ditch	3.827	....	......	....	....	....
Arnette ditch	11.448	....	......	....	....	....
Midline ditch	7.054	....	......	....	....	....
River below Midline ditch	......	....	3.647	14.043	8.0	1.76
Totals	......	....	......	165.57	98.50	....

MEASUREMENT No. 3—Made by L. R. Hope and R. E. Trimble, October, 1891.

Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
River above the Cache a la Poudre river	......	....	114.60	....	....	....
Cache a la Poudre river	......	61.11	......	....	....	....
Hoover ditch	6.40	....	......	....	....	....
Hardin ditch	1.51	....	......	....	....	....
River below Hardin ditch	......	....	244.33	75.53	8.0	9.44
Kiowa & Bijou canal	38.86	....	......	....	....	....
Putnam ditch	10.39	....	......	....	....	....
River below Putnam ditch	......	....	211.69	16.61	12.25	1.36
Weldon Valley ditch	20.93	....	......	....	....	....
Fort Morgan canal	99.35	....	......	....	....	....
River below Fort Morgan canal	......	....	103.69	15.28	13.75	1.11
Deuel & Snyder ditch	7.81	....	......	....	....	....
Platte & Beaver ditch	2.33	....	......	....	....	....
River, below Platte & Beaver ditch	......	....	134.81	38.26	11.0	3.48
Platte & Beaver Supply ditch	46.21	....	......	....	....	....
River at Snyder	......	....	186.79	98.19	13.75	7.14
Smith ditch	1.36	....	......	....	....	....
Edwards ditch	18.27	....	......	....	....	....
South Platte ditch	35.51	....	......	....	....	....
Pawnee ditch	64.70	....	......	....	....	....
River, above Merino	......	....	46.68	−20.27	18.0	−1.13
Schneider ditch	3.46	....	......	....	....	....
Springdale ditch	9.85	....	......	....	....	....
River at Sterling	......	....	66.73	33.36	13.75	2.43
Smith and Henderson ditch	6.74	....	......	....	....	....
Low-line ditch	2.12	....	......	....	....	....
Iliff & Platte Valley ditch	33.22	....	......	....	....	....
River, at Iliff	......	....	52.72	28.07	9.25	3.03
River, 2 miles above Crook	......	....	39.65	−13.07	16.50	−0.79
River, below Sedgwick	......	....	47.70	8.05	21.50	0.37
River, at Julesburg	......	....	42.96	−4.74	11.50	−0.41
Totals	......	....	......	275.27	149.25	....

GAGINGS OF THE SOUTH PLATTE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 4—Made by L. R. Hope, March, 1892.

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
....	River, above Cache a la Poudre river	......	....	473.09	....	....	....
....	Cache a la Poudre river..........	... ..	145.56	......	....	....	....
....	River, below Hardin ½ mile........	......	....	687.73	69.08	8.5	8.13
....	Kiowa & Bijou canal.............	0.50	....	......	....	....	....
....	River, 2⅜ miles below Putnam ditch	......	....	732.59	45.36	14.25	3.18
....	River, below Fort Morgan canal....	......	....	762.07	29.48	11.25	2.62
....	River, opposite Fort Morgan.......	......	....	834.72	72.65	13.5	5.38
	Totals......	......	....	......	216.57	47.50	....

MEASUREMENT No. 5—Made October 30–November 10, 1893.

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
....	River, above the Cache a la Poudre.	......	....	124.16	....	....	....
....	Cache a la Poudre river......	......	64.11	......	....	....	....
....	River, below Hardin ditch..........	......	....	257.30	69.03	8.0	8.63
....	Choat's ditch....................	4.05	....	......	....	....	....
....	River, above Putnam ditch.........	......	....	219.52	-33.73	12.25	-2.75
....	Putnam ditch.....................	12.28	....	......	....	....	....
....	Weldon Valley ditch..............	30.70	....	......	....	....	....
....	Fort Morgan canal................	132.08	....	......	....	....	....
....	River, below Fort Morgan canal....	......	....	105.29	60.83	13.75	4.42
....	Deuel & Snyder ditch.............	4.11	....	......	....	....	....
....	River, below P. & B. canal..........	......	....	151.49	50.31	11.0	4.57
....	Platte & Beaver Supply canal.....	114.12	....	......	....	....	....
....	Gill ditch........................	0.94	....	......	....	....	....
....	River at Snyder.....................	......	....	51.46	15.03	13.75	1.09
....	Smith ditch......................	8.49	....	......	....	....	....
....	Edwards ditch....................	10.20	....	......	....	....	....
....	Tetsel ditch.....................	6.94	....	......	....	....	....
....	South Platte ditch...............	44.12	....	......	....	....	....
....	Pawnee ditch.....................	11.80	....	......	....	....	....
....	River, at Merino....................	......	....	4.63	34.72	17.75	1.96
....	Schneider ditch..................	16.55	....	......	....	....	....
....	Springdale ditch.................	8.51	....	......	....	....	....
....	River, at Sterling..................	......	....	13.33	33.76	14.0	2.41
....	Smith and Henderson ditch......	11.49	....	......	....	....	....
....	Low-line ditch	6.19	....	......	....	....	....
....	Iliff & Platte Valley ditch.........	14.77	....	......	....	....	....
....	River above Iliff....................	......	....	5.72	24.84	9.25	2.69
	Totals......	......	....	......	254.79	99.75	....

MEASUREMENT No. 6—Made by P. J. Preston and R. E. Trimble, October 16–24, 1894.

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
	OCTOBER 16.						
2 p. m.	River, below Cache a la Poudre river	......	....	308.68	....	....	....
3:15	Lone Tree creek..................	......	3.01	......	....	....	....
3:50	River, below Lone Tree creek......	......	....	323.85	12.16	1.50	8.11
	OCTOBER 17.						
8:30	River, below L. T. creek, same place	......	....	345.60	....	....	....
10:30	Sterling Seepage ditch...........	6.60	....	......	....	....	....
11:15	Hoover ditch.....................	11.84	....	......	....	....	....
12:30	River, below Hoover ditch..........	......	....	389.90	62.74	3.50	17.93
2:45	Hoover ditch (waste).............	......	0.61	......	....	....	....
2:35	Box Elder creek..................	......	10.19	......	....	....	....
4:15	River, above Hardin ditch..........	......	....	349.65	-51.05	3.00	-17.02

GAGINGS OF THE SOUTH PLATTE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 6—(Continued.)

Time.	Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
	OCTOBER 18.						
7:45	River, above H'r'n ditch, same place	......	....	343.29	....	....	....
9:20	Hardin ditch	5.36	....	......	....	....	....
10:30	Illinois ditch	2.58	....	......	....	....	....
11:50	River. at head of Corona ditch	......	....	378.89	43.54	7.00	6.22
3:20	River, above Putnam ditch	......	....	385.87	6.98	5.25	1.33
2:45	Putnam ditch	27.90	....	......	....	....	....
	OCTOBER 19.						
8:25	Weldon Valley ditch	36.98	....	......	....	....	....
10 a. m.	River, above Kiowa creek	......	....	369.81	48.82	8.50	5.74
12:20	River, below Kiowa creek	......	....	375.07	5.26	1.75	3.01
2:15	Fort Morgan canal	170.30	....	......	....	....	....
2.55	River 3⅜ miles below Fort M. canal	......	....	219.00	14.23	7.0	2.03
	OCTOBER 20.						
9:15	River, above Bijou creek	......	....	278.45	59.45	5.75	10.34
11:55	Deuel & Snyder ditch	3.65	....	......	....	....	....
2:35	Platte & Beaver canal	77.28	....	......	....	....	....
12:05	River, below Bijou creek	......	....	152.09	-45.43	1.75	-25.96
3:50	Platte & Beaver Supply canal	71.90	....	......	....	....	....
4:05	River, below P. & B. Supply canal	......	....	131.54	51.35	8.00	6.42
	OCTOBER 21.						
9:10	Parson ditch	4.95	....	......	....	....	....
10:05	Smith ditch	9.06	....	......	....	....	....
10:15	River, at Snyder	......	....	142.37	24.84	5.75	4.32
1:30	River, below Big Beaver creek	......	....	149.63	7.26	5.75	1.26
5 p. m.	South Platte ditch	60.01	....	......	....	....	....
	OCTOBER 22.						
8:25	Pawnee ditch	99.55	....	......	....	....	....
9:20	River, at Merino	......	....	41.48	51.41	12.25	4.20
10:50	Schneider ditch	20.33	....	......	....	....	....
11:40	Springdale ditch	22.66	....	......	....	....	....
1:20	River, above Pawnee creek	......	....	20.80	22.31	9.00	2.48
3 p. m.	River, below Pawnee creek	......	....	24.32	3.52	1.75	2.01
4:20	Henderson and Smith ditch	2.08	....	......	....	....	....
	OCTOBER 23.						
9:45	River, above Cedar creek	......	....	30.36	8.12	10.00	0.81
11:30	Iliff & Platte Valley ditch	4.14	....	......		....	....
10;35	River, below Cedar creek	......	....	35.93	9.71	1.50	6.47
3:50	River, 2½ miles above Crook	......	....	36.07	0.14	17.25	0.01
	OCTOBER 24.						
8:20	River, at State line	......	....	1.90	-34.17	36.00	-0.95
	Totals	......	....	......	301.19	152.25	....

MEASUREMENT No. 7—Made by L. G. Carpenter and P. J. Preston to Sterling, and by P. J. Preston and R. E. Trimble from Sterling to Julesburg, October, 1895.

OCTOBER 21.						
Cache a la Poudre river	......	123.02	......	....	....	....
River below the Poudre	......	....	826.55	....	....	....
Lone Tree creek	......	5.24	.....	....	....	....
OCTOBER 22.						
Hoover ditch	6.07	....	......	....	....	....
River below Hoover ditch	......	....	939.95	114.23	3.50	33.0
Hoover ditch	......	4.47	......	....	....	....
Sterling Seepage ditch	......	(3.86)	......	....	....	....
Box Elder	......	0	......	....	....	....
Illinois ditch	0	....	......	....	....	....
River above Hardin ditch	......	....	909.15	-35.27	4.50	-8
Hardin ditch	6.74	....	......	....	....	....
OCTOBER 23.						
Corona ditch	10.00	....	......	....	....	....

GAGINGS OF THE SOUTH PLATTE RIVER.

(In cubic feet per second.)

MEASUREMENT No. 7—(Continued).

Place of Measurement.	Out-take.	In-flow.	River.	Gain.	No. of Miles.	Gain per Mile.
River above Putnam ditch	......	....	935.36	42.95	12.25	3.5
Lost creek	......	0	......	....	....	....
Putnam ditch	14.38	....	......	....	....	....
Kiowa creek	......	0	......	....	....	....
Weldon Valley ditch	86.85	....	......	....	....	....
OCTOBER 24.						
River at Orchard	......	....	940.73	106.60	8.25	12.92
Seepage ditch	......	(4.10)	......	....	....	....
Fort Morgan canal	208.28	....	......	....	....	....
River, at Shaffer's ford	......	....	778.37	45.92	9	5.10
OCTOBER 25.						
River, above the Bijou	......	....	861.85	83.48	5.75	14.50
Bijou creek	......	(4.84)	......	....	....	....
OCTOBER 26.						
Platte & Beaver canal	100.39	....	......	....	....	....
Deuel & Snyder ditch	14.70	....	......	....	....	....
River, at Fort Morgan	......	....	745.21	—3.97	4.25	—0.93
Pyott ditch	15.58	....	......	....	....	....
Platte & Beaver supply	55.72	....	......	....	....	....
Smith ditch	2.88	....	......	....	....	....
River, at Snyder	......	....	685.85	14.82	11	1.35
OCTOBER 27.						
River, 5 miles below Snyder	......	....	751.23	65.38	5	13.08
Tetsel ditch	.90	....	......	....	....	....
Johnson and Edwards ditch	18.06	....	......	....	....	....
South Platte ditch	4.80	....	......	....	....	....
Pawnee ditch	129.00	....	......	....	....	....
OCTOBER 28.						
River, at Merino	......	....	691.63	93.16	13	7.17
Schnieder ditch	14.60	....	......	....	....	....
Springdale ditch	38.59	....	......	....	....	...
Sterling No. 1 ditch	10.63	....	......	....	....	....
Smith and Henderson ditch	2.97	....	......	....	....	....
OCTOBER 29.						
River, at Sterling bridge	......	....	671.64	46.80	13.75	3.40
Iliff ditch	0	....	......	....	....	....
River, at Iliff	......	....	688.63	16.99	9.25	1.84
OCTOBER 30.						
Powell and Dillon ditch	3.04	....	......	....	....	....
McPhee and Mullins ditch	10.42	....	......	....	....	....
River, at Crook	......	....	626.12	-48.05	19.00	—2.53
NOVEMBER 1.						
Henry Fuller ditch	3.07	....	......	....	....	....
South Side Res. Co. ditch	2.37	....	......	....	....	....
Tom Little ditch	(2.19)	....	......	....	....	....
River, at Pole creek	......	....	633.23	14.75	24	.61
OCTOBER 31.						
River, at State line	......	....	585.60	-47.63	9.50	—5.01
Total	......	....	......	....	152.25	....

TABLE IV.

SUMMARY OF PRECEDING TABLES, SHOWING GAIN IN SEEPAGE OF SOUTH PLATTE RIVER.

(In cubic feet per second.)

	No. of Miles.	Oct. 1889.	Oct. 1890.	Oct. 1891.	Mar. 1892.	Oct. 1893.	Oct. 1894.	Oct. 1895.	Ave.
Mouth of Poudre to Hardin ditch	8	49.0	68.7	75.5	69.1	69.0	23.9	79.0	62.0
Hardin ditch to Putnam ditch.........	12	....	-18.8	16.6	45.4	-33.7	50.5	43.0	17.2
Putnam ditch to Fort Morgan canal....	14	51.3	27.0	15 3	29.5	°60.8	°68.3	°152.5	57.8
Fort Morgan canal to P & B. canal ...	11	....	6.5	38.3	*72.7	50.3	65.4	....	46.6
P. & B. canal to Snyder..............	14	....	17.1	98.2	....	15.0	24.8	94.3	49.9
Snyder to Merino.....................	18	79.6	21.3	-20.3	....	34.7	58.7	158.5	55.4
Merino to Sterling...................	14	32.8	29.7	33.4	...	33.8	†25.8	46.8	33.7
Sterling to Iliff	9	4.4	14.0	28.1	....	24.8	17.8	17.0	17.7
Iliff to Crook.......................	17	....	....	-13.1	....	....	0.1	-48.1	-20.3
Crook to State line	36	....	....	3.3	....	....	-34.2	-32.9	-21.3
Totals......	151	217.1	165.5	275.3	216.7	254.7	301.1	510.1	298.7
Average per mile.....................	..	2.2	1.7	1.8	1.6	2.6	2.0	3.4	2.0

*Opposite Fort Morgan. °Schaefer s Ford. † Below Pawnee.

§ 24. We also include the results of the measurements on the Upper Platte, from the canon, 22 miles above Denver, to the mouth of the Cache a la Poudre, a total distance of 74 miles. The measurements were usually made continuous with those of the Lower Platte, though here given separate. In 1895 they were made after the Lower Platte was completed. These measurements were made under direction of the various State Engineers, with the exception of the first, which was made under direction of Col. E. S. Nettleton in connection with the U. S. Irrigation Survey.

TABLE V.

SEEPAGE INCREASE OF THE UPPER SOUTH PLATTE FROM CANON.

(In cubic feet per second.)

	Distance in Miles from Canon.	Oct. 18, 1889.	Oct. 14, 1890.	Oct. 23, 1891.	Mar. 7, 1892.	Oct. 30–Nov. 1893.	Oct. 29–Nov. 4, 1894.	Nov. 1895.	Average.
To head of City ditch................	6	....	8.95	27.6	26.0	18.4	49.2	19.4	24.9
" Littleton	12	59.30	18.9	83.2	73.9	50.1	84.6	80.4	64.3
" Denver	22	64.1	70.8	105.0	137.4	94.9	221.6	198.2	127.4
" Fulton ditch	28½	....	110.4	146.5	149.4	138.8	256.0	179.0	163.3
" Brighton	35½	91.6	115.8	184.8	124.5	164.6	306.0	214.1	171.6
" Elwood and Wheeler ditch.......	44½	133.6	191.3	228.3	145.7	220.4	342.6	272.0	219.1
" Platteville......	51⅛	147.9	....	236.5	189.9	230.6	371.0	336.8	252.1
" above St. Vrain..................	56⅛	....	172.7	242.9	....	....	....	....	(207.8)
" Union ditch	60⅛	161.4	....	....	....	264.5	426.6	357 5	302.5
" Latham..........................	68	211.5	192.8	308.8	202.7	291.7	478.4	381.1	295.3
" Cache a la Poudre river...........	74	260.*	232.1	335.7	226.0	329.9	501.8	438.3	332.0

*Interpolated.

The sums given in this table will be found to differ from those given in the reports of the State Engineer. In many cases the seepage collects in side channels, and runs to the river. Where there is good reason to know that it is seepage, it seems better to include this as a part of the seepage inflow of the river. The examination

of numerous channels has shown that in almost all cases they are dry above the lines of the ditches. In some cases waste from irrigation and from ditches, not seepage, also reaches these channels. As a rule, along the line of the Platte, there is little wasted, especially at the time of this measurement. To eliminate the waste, the inflow from the same channel was compared in the various years, and in cases where unusually large, the excess is counted as waste. The inclusion of these lateral inflows causes an increase of the amount by about twenty feet on the average to the mouth of the Poudre.

RELATION TO AREA IRRIGATED.

§ 25. If the water returned comes from the water applied in irrigation there should be a relation between the amount of water applied and the amount returning to the river as seepage. There should also be a relation between the area irrigated and the amount of return. There are so many interfering conditions, that we cannot expect to find the relation a very close one, even had we the means to know the total area, or the total amount of water applied, with accuracy. A portion of the water applied raises the water table or the height of the water in the soil. The land newly irrigated gives no material return for several years, as most of the excess of water applied fills the subsoil. If the land is some distance from the river the element of time also enters. In the case of the Poudre river, there have been many seepage ditches constructed for the purpose of taking the seepage water before it reaches the river, and again applying it to the land. In the aggregate they use a considerable number of second-feet. The increase as shown in the tables should be increased by the amount thus used. The relation between the seepage and the area irrigated will be obscured by these and other causes. The return for any one year is not from the water applied in that or in any other one year. It is rather the result of the applications of several different years at different distances. Hence, while the amount varies from year to year, the variation from one year to another is less necessary to take into account as the strip irrigated becomes of greater width. In the case of the Poudre valley and also in the Platte, the area under irrigation has steadily increased since the first measures were made. The total amount irrigated in the Poudre valley may be considered as between 120,000 and 135,000 acres. The latter sum was used in bulletin No. 22, on the "Duty of Water."

Table VI. gives the data regarding the principal ditches in the valley, and is given in full to show the character of the land devoted to agriculture. In this table, column 3 includes the total amount of land supplied with water rights under the canals. The waste and pasture land includes much that is not irrigated, and some that is. Hence the difference, given in column 11, is really less

than the area irrigated, if the figures are otherwise correct. The area shown by this table as irrigated in 1894, exceeded 116,000 acres. In the previous year it was less. The increase amounted to several thousand acres per annum, principally under the outer ditches, and at the lower end of these canals. The drainage from a portion of this area does not enter the Poudre, but instead it enters the Platte directly, and through the Lone Tree and Crow creek valleys. This seepage has amounted to probably not less than from twelve to twenty second-feet during the past few years, but is included in the seepage of the Platte and cannot be separated. But, considering that all this area is tributary to the Poudre, we have from 116,000 acres a return of 104½ cubic feet per second on the average, or one cubic foot per second from each 1,100 acres irrigated. The seepage known to be caught and stored in reservoirs is more than enough to make the return one cubic foot per second for less than 1,000 acres. In 1895 it amounted to one cubic foot per second to every 700 acres. In the case of the Platte, one cubic foot per second returns from still fewer acres.

TABLE VI.

Reference Number.	Name of Canal.	Total Acres.	Pasture and Waste Land.	Acres Alfalfa.	Grass.	Other Crops.	Wheat, Oats and Barley. No. of Bushels.	Corn, No. of Bushels.	Potatoes, No. Sacks.	Total Acres, Less Waste and Pastures.	Amount of Water Applied, 1894. Acre-feet.
(1)	(Col. 2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	N. Poudre canal	9.074	7.081	843	795	2.430	63,626	3,775	5,687	1.993	18,306
2	Box Elder canal	1,280	1,000	50	....	100	1,200	25	200	280	.....
3	Canon	497	197	160	5	90	427	300	500	300	.....
4	Larimer Co.	27,844	11,131	4,010	....	12.847	120,838	4,075	113,795	16,713	27,830
5	Jackson ditch......	3,160	991	1,131	223	453	5,246	....	350	2,169	7,984
6	Small ditches, n. side	2,054	453	786	145	886	4,542	100	2,770	2.101	....
7	Larimer & Weld.....	59,507	15,123	7.428	878	32,182	390,601	6.702	554,303	44.384	77.225
8	Pleasant Valley & L.	8,221	3,110	1.750	470	2.234	19.746	1,972	3,655	5,111	17,387
9	New Mercer	4,256	1,867	1,664	174	1,020	48,015	2,032	13,448	2,389	11,110
10	Larimer Co. No. 2..	8,623	985	2,751	61	2,680	56.191	280	10,389	7,638	18,545
11	Fort Collins.........	1,179	374	492	45	387	1,944	65	860	805	.....
12	Box Elder	1,735	1,028	270	144	351	3,178	95	3,184	707	.....
13	Watrous, W. and S..	120	75	20	....	25	......	....	600	45	.....
14	Ames, P. and C. d's.	1,468	1,303	409	295	646	17,036	1.755	11,070	165	.....
15	Lake	6,242	2,076	1,007	156	1.762	36.698	3,855	23,280	4,166	11,262
16	Cache a la P. No.2..	33,173	11,128	5.032	704	15,065	236.689	3,670	602.485	22,045	70,610
17	Whitney	2,080	683	358	55	652	10.461	100	17,500	1,397	.....
18	Eaton and Jones....	360	149	75	119	135	1,900	250	2,240	211	.....
19	No. 3	1,275	480	147	103	517	3,015	....	14,652	795	.....
20	Boyd and Freeman..	900	158	90	350	300	3,150	300	7,000	742	.....
21	Ogilvy	3,800	1,728	720	....	1,357	20,755	....	29,660	2.072	.....
	Totals	176,848	61,120	29,193	4,722	76,119	1,045,258	29,351	1,417,628	116,228	260.259

§ 26. The foregoing table shows the distribution of the irrigated land, and of the water applied in the valley, according to the canals. The record is taken from the figures obtained by Water Commissioner Tenney in 1894, and include the first complete data for the entire valley. The data gives nearly the relative quantities,

and is far better than other records available. Some of the figures will be referred to later.

§ 27. On the Lower Platte the extent of the irrigated area is not so well known as on the Poudre. This portion of the valley includes two districts—Water District No. 1, from the mouth of the Poudre to the east line of Morgan county, just below the head of the Tetsel ditch, and No. 64, from that point to the State line. In the report of the Commissioner for district No. 1, for 1890, the total amount irrigated is given as less than 11,000 acress. In 1892 it is given as 43,730 acres. This latter is probably excessive. The amount is reported in 1895 as practically the same, distributed among the ditches as follows:

	Acres.
The Hardin ditch	525
The Hoover and Illinois ditches	720
The Putnam ditch	1,875
The Weldon Valley	6,250
The Fort Morgan	12,600
The Platte & Beaver	14,080
The Platte & Beaver Supply	9,500
Deuel & Snyder	1,000

In district 64, through the courtesy of Mr. Patterson, the Water Commissioner for that district, we are given the following approximations:

	Acres.
South Platte ditch	3,500
The Pawnee	4,700
Schneider	2,600
Sterling Irrigation Co.	4,400
Henderson and Smith	1,275
Sterling No. 2	1,800
Low Line	1,900
Springdale	3,200
Powell and Dillon	930
Iliff & Platte Valley	5,000
Small ditches	6,000
Or a total of	35,000

This makes a total acreage for the valley of about 75,000 to 80,000 acres. With an average inflow of 340 cubic feet per second from the mouth of the Poudre river to Iliff, this is an inflow of one cubic foot per second from 220 to 240 acres irrigated. This is far more than in the case of the Cache a la Poudre. It is to be noticed that in the case of the Platte, a relatively large proportion of the irrigation is given to the bottom lands, which are used for hay. The principal exceptions are in the vicinity of Fort Morgan

and Sterling. The river overflows the bottoms many years, and did so in 1893, 1894 and 1895, and soaks them with water sometimes for a considerable period. More water is applied in the bottom irrigation than in the uplands. The practice of fall irrigation is very extensively followed. The river then having sufficient water, all the lands with few exceptions are soaked. We do not have measurements to show how much water is thus applied, but from what I observed, and from the conditions, the watering seems to be relatively a very profuse one. This land receives more water than an equal area on the Poudre, and is, as a whole, much closer to the river. These conditions tend to give a more profuse and a speedier return to the Platte.

On the Upper Platte, the conditions have not been under observation, and the areas are not well known. The seepage of fully half a million acres drains into this portion of the Platte and the tributaries which flow into it. In the cases of the latter, the construction of numerous seepage ditches have interfered with the natural flow of the water, so that the amount which reaches the river is much less than the total amount of seepage. A portion of the land irrigated from these lateral streams drains directly into the Platte. This is especially the case with Clear creek. According to the reports of the Superintendent of Irrigation of this division to the State Engineer, there have been, using round numbers, 58,000 acres irrigated in district No. 2, including the Platte from Denver to the mouth of the Poudre; 39,500 in district 8, which includes the Platte from Denver to the canon. This is a total of 98,000 acres irrigated directly from the Platte. In addition to this there are about 45,400 acres draining into the Platte which are irrigated from Bear creek, Clear creek, St. Vrain and Big Thompson, making a total of 143,000 acres lying along the Platte and tributary thereto. This sum is rather above than below the truth. Comparing with the total inflow, we have an average return of 332 cubic feet per second from 143,000 acres, or one cubic foot per second from 430 acres.

During the first four measurements the average return was 264 second-feet, and during the last three, 423 second-feet. The latter is at the rate of one second-foot for each 238 acres. It is certain that many acres of the land in this valley returns but little water to the stream. Whether the rate of increase noted in the table from year to year will continue, further measurements are necessary to determine.

RELATION BETWEEN SEEPAGE AND AMOUNT OF WATER APPLIED.

§ 29. An attempt was made to determine the amount of land the drainage of which enters each of the lateral channels and enters the river between the points of measurement, thinking that

this might explain some of the exceptional gains. But still better is the amount of water which is applied, if it can be known. A manuscript map was prepared, showing the location of the water rights in the principal canals. A water right usually includes the right to the water for 80 acres. From this map a table was prepared, showing the number of rights draining into the river between the different points of measurement. From the amount of water used by the different ditches during the year, as shown in Table VI., this could be expressed in acre-feet of water, or in the number of acres which would be covered by the water one foot in depth. The inflow can not be expected to be very closely proportional to the area irrigated or the amount of water applied between these points, or not until after a series of years. The return is slow, and there is reason to think that the seepage from some of the outer ditches has not yet reached the river. The construction of seepage ditches, to drain the seepage water from the water-logged land, or to catch the seepage water, also interferes with the normal distribution. They collect and carry the water sometimes a number of miles from where it appears. The effect of the seepage ditches is to increase the apparent return near the lower end of the stream. The amount of water lost from the canals is much more than from an equal area of irrigated land. An area of one acre forming part of a canal channel loses as much water as 200 to 400 acres of land under ordinary irrigation. The losses near the heads of the canals, especially those near the mountains, is greater than the average. An estimate of the number of acres of canals would be desirable before the study can be completely satisfactory.

From Table VI., we find 260,000 acre-feet of water is applied to 106,000 acres. This includes loss and waste from the canals, and is equivalent to a depth of 2.45 feet over the entire area irrigated. If this depth were applied by the smaller canals too, we have 284,000 acre-feet applied in the whole valley.

As a rule, the smaller canals have earlier appropriations from the river, and therefore use water more freely; hence it is safe to assume that at least 284,000 acre-feet of water have been applied to the irrigated area. The amount of water which is applied is affected by the stage of water in the river. When the river is high the canals are full, water is unstinted. If low, the amount used is decreased. In this case the ditches of later construction are the first to suffer. The development of storage reservoirs has increased the amount applied late in the season, especially since 1892. At present the reservoirs already in use in the valley of the Cache a la Poudre have a storage capacity of about 48,000 acre-feet. Of the 284,000 acre-feet applied to the whole valley, about 35,000 acre-feet is applied so that it drains into the channels running into the Platte. Deducting this, as it does not affect the inflow into the Poudre, we

then have an inflow reaching the Poudre of 104 cubic feet per second, from an application of 250,000 acre-feet, or a constant flow of one cubic foot per second from each 2,400 acre-feet applied. The amount is actually greater than 104 second-feet, because of the amount, at present unknown, which is caught by the seepage ditches. As one cubic foot per second corresponds to 724 acre-feet in the course of a year, there is a seepage return of 724 acre-feet from 2,400 acre-feet of water taken from the river. If the seepage from the outer canals has not yet reached the river, then an actual application of much less than the 2,400 acre-feet gives the observed return. What the exact proportion is cannot be determined in this valley for some years to come, after all the land irrigated furnishes its portion of the seepage to the stream.

§ 30. Bringing together the amount of increase in different parts of the Cache a la Poudre and the area of irrigated land which drains into the same section, we have Table VII. In the third column is given the amount of water applied to that portion of the valley whose natural drainage is into the river between the points indicated in the first column In the fourth column is given the per cent. of the total amount applied to the whole valley. In the column headed "Computed inflow" is given the amount of inflow there would be if the inflow were in exact proportion to the amount of water applied. How much land will furnish underflow to a given part of the river cannot be very closely told, even with detailed knowledge of the topography and the location of the farms where water is applied. The course of the underground drainage can be told in most cases, until the river bottom is reached. Thence the channels often end in sloughs, and sometimes follow old river channels, or the water is collected in seepage ditches, which carry it sometimes for considerable distances. From our present maps the limit of the drainage areas cannot be told with sufficient accuracy to make the areas and the amount of water applied, given in the third column, anything but an approximation. The table shows, however, that the relation is close enough to be more than accidental, and in future years, when the influence of the outer area begins to be felt, may be expected to be closer.

It shows that there is a reason for the large amount of increase observed in the last few miles of the Poudre, before it empties into the Platte.

In the case of the increase from the No. 2 canal to the Pump house, and from the Pump house to the Ogilvy ditch, it may be stated that a portion of the drainage above the Pump house enters the bottoms above that place, and does not enter the river until below that point. While the water applied is counted in the section above the Pump house, the seepage is included in the section below. It has not been possible to estimate this, and it is

therefore noted as a disturbing condition. Likewise, some of the seepage which should enter the next section between the Pump house and the Ogilvy ditch, enters the river lower down.

TABLE VII.

	Distance in Miles.	Water Applied.		Average Inflow from Seepage.			
		Acre-feet.	Per Cent. of Total.	No. Years Observation.	Observed.	Computed.	Observed gain per Mile.
Canon to L. & W. canal	7.25	18,400	7	9	15	8	2
L. & W. to No. 2 canal	10.10	51,800	21	9	21	21.6	2
No. 2 to Eaton canal	3.0	37,000	15	..	....	....	....
Eaton to No. 3	9.0	30,300	12	..	....	....	....
No. 3 to Pump house, Greeley	3.0	46,700	18	..	....	....	....
No. 2 to Pump house, Greeley	15.0	114,000	45	7	28.6	48	2
Pump house to Ogilvy ditch	2.5	23,100	9	8	19.2	10	8
No. 2 to Ogilvy ditch	17.5	137,100	55	9	45.2	57	2.5
Ogilvy to mouth of Poudre	4.0	42,700	17	8	23.8	18	6
Beyond mouth of Poudre	....	38,000	..	..	....	....	....

THE EFFECT OF TEMPERATURE ON THE INFLOW.

§ 31. The effect which temperature might have upon the amount of inflow was not considered of any importance until the unexplained differences caused a consideration to be given to its possible effect. It is known that low temperatures increase the viscosity of water. The effect is especially noticeable in the flow through small tubes, so much so that five times as much water will pass through a capillary tube at 200° as at 32° F. The effect has been noticed on the amount collected by drains, and in varying the discharge in cases like those of the gathering pipes of the Denver Water Co., in the bed of Cherry creek. A comparison between the soil temperatures at the Colorado Agricultural College and the inflow into these gathering galleries has been made in bulletin 38 of the Utah Experiment Station. As our measurements of the seepage were nearly all taken in the same month, it was not thought that the difference of temperature would be sufficient to affect the quantity of flow. But it may have a much greater effect than was at first thought probable. The water-carrying stratum lies at different depths, and is of different thicknesses. Its temperature therefore varies. Besides, the descending water carries down the temperature of the surface to some extent. Still, the indications of the soil thermometers may be taken to show the variations in the temperature of the seepage water at the time of gaging, and hence give the means of estimating the effect of temperature.

The readings of the soil thermometers will not be far from the temperatures of the soil at the corresponding depths throughout the Cache a la Poudre and the Platte valleys. There are three sets of

thermometers: One in well-drained irrigated soil; one in low, undrained irrigated soil, the water standing within six feet of the surface; and one in well-drained unirrigated soil. At a depth of six feet the variation during the year is from 20° to 24°, being least in the low ground. At three feet in depth the range is 32°. At six feet the highest temperature of the year is reached early in September, the lowest early in March. Its temperature thus lags six or eight weeks behind the temperature of the surface. At three inches depth the annual range is about 70°. With the range of temperature at the depth of six feet, other conditions remaining the same, one-third more water would flow in August than in March, and at a depth of three feet, nearly one-half more.

But as the gagings of the different years were made at almost the same time, the difference in temperature is comparatively small, and the effect in different years for the same month will be less marked. Nevertheless it is not insignificant.

The table shows the average temperature at three and six feet depth during the time of the gagings of the Poudre river, and the amount of inflow found is shown in the fourth column.

Had the temperature been uniformly 60° instead of that observed, the amount of seepage would have been that given in the last column. This is under the supposition that the temperatures at three and six feet in depth from the surface will be the most influential. The correction is obtained by determining graphically the co-efficients of viscosity from the co-efficients, at 32°, 50°, 68°, etc.†

TABLE VIII.

TEMPERATURE OF SOIL AT 3 AND 6 FEET BELOW SURFACE, AND ITS EFFECT ON SEEPAGE.

YEAR.	Thermometers. Set A.	Thermometers. Set B.	Am't of Seepage in Poudre River.	Am't Corrected for Temperature of 60°.	
Oct., 1889	57.8	59.4	99.0	101	Set A in dry, well-drained irrigated soil.
Oct., 1890.....	58.7	56.2	100.8	104.8	Set B in low ground, water standing within six feet of the surface.
Oct., 1891.....	55.7	54.9	84.6	90.4	
Mar., 1892.....	38.9	40.0	*96.	122.0	
Oct., 1892.....	60.4	59.9	101.6	101.4	
Nov., 1893.....	51.5	53.4	98.7	108.6	
Mar., 1894.....	36.2	37.9	82.3	107.2	
Aug., 1894.....	64.3	62.5	118.2	113.5	
Oct., 1895.....	52.2	52.3	164.4	187.4	

* To Ogilvy ditch.

The amount of return throughout the year is sensibly the same, the principal disagreement being the one for March, 1892, when the gain in less than the full distance would have been 122 second-

† Daniell's Physics, p. 306.

feet, and in 1895, when the gain was much greater than in previous years. The large gain corresponding to March, 1892, is probably due to the fact that this measurement was taken immediately following a storm, which had covered the ground with snow, and, slowly thawing, had filled the surface of the soil. Such a case as has been shown by King, makes its influence felt at once on the underground water, even though the intermediate space be dry. The return for 1891 is less than the average amount. There is a doubt concerning that gaging. The measurements of the lower part of the stream from the Pump house, at Greeley, to the mouth of the Poudre, were made by Messrs. Hope and Trimble, who continued down the Platte, while the upper ones were made by other parties. The results of the lower party were taken and compared with those of the upper. It is possible that the interval of one day, or the use of different meters, may have had some effect.

There is a sensible increase after allowing for the effects of temperature.

RAPIDITY OF FLOW OF SEEPAGE OR UNDERFLOW WATER.

§ 32. Inquiries for information regarding the movement of underground waters is so frequent, that though it was not intended to say anything on the subject in this bulletin, it is desirable to give a brief statement of the facts as they appear to be.

Direct evidence of the speed with which water passes through any considerable distance underground is almost entirely wanting. Attention has been awake to evidence bearing upon the question, but in the course of extensive travels over much country for some years almost none has been encountered. Cases where lands have been seeped subsequent to the construction of a ditch have been sought, but most cases have been complicated by other conditions, which make the answer anything but conclusive. Subsequent experience has also led to the conclusion that the appearance of seepage may give very unreliable testimony. For example, on the grounds of the Colorado Agricultural College a well was sunk about 200 feet from a canal and about ten feet lower. In the course of some measurements on the well, it was found that whenever water was turned in the ditch the water began to rise in the well within twelve hours. There is every reason to doubt that water passed that distance in that time. The case is similar to that where water is turned in a hose. If the hose is already full of water, water immediately begins to run from the lower end. If the hose is empty, some time will be required to fill the hose before the water begins to run. If already full, the pressure is transmitted in very short time, and the increase which is seen very often in the flow of seepage when water appears in a neighboring canal may be due to the transmitted pressure, rather than to the direct passage of water.

Where there is a periodical change in the head supplying the water, as in the case of the canals, there may be a series of underground waves affecting the height of the ground water. The rise and fall of such a wave, which started years before, may be mistaken for the rise and fall due to the periodical rise in the canal.

Thus the case of the Natron ponds, which rise in March, and are located thirty-five miles from the Nile, and which Storer (*Agriculture*, 1:56) attributes to the rise of the Nile of the previous September, is probably such a case.

§ 33. The best case met with was near Montrose. A deep gulch starts in the mesa below the Montrose canal. Passing across this depression the glistening in the moonlight of the alkaline deposit on the shale at the bottom attracted my attention, and on inquiry it was learned that this began to show slightly two years after the canal was used, and in considerable quantity in three years. The distance from the canal is three miles. This would make the speed about one mile per year.

§ 34. Direct experiment on the rapidity under field conditions have been unsatisfactory or inconclusive. Col. E. S. Nettleton, as Chief Engineer of the U. S. Irrigation Investigation for the Department of Agriculture, aided by W. W. Follett, attempted to determine the rapidity in the sands of Cherry creek, and on the Rio Grande, but with inconclusive results, except to come to the conclusion that the velocity was very slow. *

In the sands of the Fountaine qui Bouille, Mr. D. C. Henny concluded that the water had a velocity of about seven feet per hour. † The method of arriving at this determination is not given. From other evidence it would seem to be excessive.

Water Commissioner J. T. Hurley, of Orchard, reports that under the Weldon Valley canal the seepage has progressed one and one-half miles in five years. In one case under the Larimer County canal, according to Mr. N. C. Alford, it was five years before seepage showed at a distance of forty rods from the canal, though the slope was considerable. In one case near Greeley, according to Mr. S. A. Bradfield, it seems to have taken about ten years to go two and one-half miles.

§ 35. The rate is certainly slow, and observers throughout the State whose attention has been called to it now agree upon its small progress. A few years ago most of them believed in a rapid flow, as still do most of the adherents in the belief that there is a great "underflow" under the plains.

Comparison with familiar facts would lead one to expect slow progress. The water in passing through sand and gravel must

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* Final report Artesian and Underflow Investigation; Pt. 2, p. 34.

† Quoted by J. D. Schuyler, report as consulting engineer to the Pueblo Gravity Water Co.

pass through small openings, which form a series of minute, tortuous and long tubes. It is a fact of common observation that the pressure of water is much reduced by attaching a short length of hose or pipe. In the case of flow through sands, the openings are many times smaller, and the length may be very great, hence no matter how great the fall, the effect of the pressure is throttled by the friction.

§ 36. In the lack of direct field evidence, we need to resort to laboratory experiments. An accomplished French engineer in investigating the water supply for the city of Dijon, experimented upon the flow through sand. He used a cast iron tube twelve feet long and twelve inches in diameter filled with sand, measuring the amount of water which passed through under different heads, and determined the relation between the pressure and the velocity. *

§ 37. From the experiments of Darcy developed by Dupuit †, it is found in minute channels the velocity varies directly as the head, and may be expressed by the equation,

$$v = k\,i$$

in which v represents the velocity, i the inclination (being the head or fall in a given distance divided by the distance), and k a factor which varies with the kind of soil, size of interstices, etc. This factor varies widely in different soils. It can be determined by experiment in specific soils, and the results there obtained applied to others of similar character.

Table IX. is an attempt to put into tabular form, which will be practically useful, the value of the factor k for different cases. The table gives the factor by which the rate of inclination or grade (expressed by the fall in feet divided by the distance in feet) is to be multiplied to give the velocity in feet for the unit of time given in the corresponding column. The table is made from data obtained from the filters of London, Paris and Berlin, through Professor Nazzini, of Rome. ||

§ 38. Since water is more viscous at low temperature than at high, the formula given in § 37 should evidently include a factor depending upon the temperature. From the experiments of Poiseulle ‡ this factor would be $1+.00187\,(t-32°)+.00007\,(t-32°)$ for any other temperature than freezing.

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* Darcy, Les eaux publiques de la ville de Dijon.

† Traite de la conduite et de la distribution des eaux. Darcy and Dupuit I have not had the opportunity to consult at first hand.

|| Idraulica pratica, 1:608.

‡ Recherches experimentales sur le mouvement des liquides dans les tubes de tres petite diametre. Quoted, Jamin et Bouty, Physique, tome 1, pt. 2, p. 100; also see Daniell's Physics, p. 308.

TABLE IX.

TABLE FOR VELOCITY OF FLOW THROUGH PERMEABLE SOILS.

Values of k in formula, $v=k\,i$, for different units of time: v is velocity in feet; i is the inclination or fall in feet per foot.

Kind of Material.	Size Grains, in Inches.	Voids, Proportion of.	Velocity. Per Second.	Per Hour.	Per Day.	Per Year.
Minute Gravel	.08	0.41	.024	86.47	2075	757520
Coarse Sand	....	0.38	.0026	9.33	224	81730
Fine Sand	.008	0.35	.00047	1.69	40.5	14777
Sandy Soil	....	0.30	.00022	.79	18 9	6897
Sandy Clay	....	0.25	.00012	.42	10.2	3725
Clay {	....	0.20	.00003	.12	2.8	1035
	....	....	.00008	.295	7.1	2587

EXAMPLE.—What distance will water pass through coarse sand in a year, inclination about 1 in 100?

Here i=1-100. If the sand averages 1-10 inch diameter, without finer particles, it would approach what is here designated as minute gravel. In one year the distance would be the number 757,520 multiplied by the inclination, 1-100, giving a distance of 7,575 feet, or about one mile and a half. If in coarse sand, as here termed, a distance of about 800 feet.

If the movement is downward, then i is 1. If there is a head in addition, then i may be greater than 1.

§ 39. An opportunity to measure the loss by seepage from a canal, and, indirectly, the rapidity of passage of water through the soil, occurred at the time of making the seepage measurements. The Fort Morgan canal is of considerable size. It was measured about three miles below the headgate. Another measurement was made at a point 7.4 miles from the first, at the head of the old flume across Bijou creek. Two small laterals between were withdrawing water. This was measured and taken into account. For much of the distance the canal skirts the bluffs between the bottoms and the up-lands. For part of the way the soil is very sandy. At the first point of measurement the canal was carrying 208.28 second-feet; at the second point, 183.83 second-feet. The intermediate laterals withdrew 4.37 second-feet. Hence the loss, including seepage and evaporation, amounted to 20.08 second-feet. The evaporation from the surface, averaging forty-five feet wide, under the conditions of temperature of water and air cannot exceed one-fourth of one cubic foot per second, by use of formula in annual report of 1891.*

Practically, therefore, the whole loss is seepage. This stretch of the canal has not been cleaned for some years, except that in

* Annual report, Section Meteorology and Irrigation Engineering, Report Colorado Experiment Station, 1891, p. 51.

1895 some material was taken from the bed of the canal to strengthen the banks.

§ 40. A new section had been built on the same canal to avoid a long flume on the old line. Water had been running in the new portion for three weeks at the time it was visited. The total length of the new portion is 10,100 feet, including 400 feet of flume. A measurement was made of the water of this section, both at the upper and lower ends. Some water was running through the old flume. The amount decreased from 109.15 second-feet, to 97.67 second-feet, in passing through the new channel, or there was a loss of 11.48 second-feet. The new flume was so nearly water tight that its leakage may be neglected.

§ 41. In these two cases we may estimate the rapidity of the flow of water through the soil. In the first case, the loss of twenty feet took place in a distance of 7.4 miles. The average width of the channel was 45 feet, hence the area of the canal in this distance was nearly forty-one acres. The loss corresponds to a layer of water of 11.7 inches deep in twenty-four hours. As the water occupies a space of about one-third of the sand, its velocity through the sand is three feet per day. It is unquestionably true that the loss takes place at unequal rates in different portions of this stretch, so that this rate, as in those which follow, is an average one for the section considered.

In the second case, the loss was 11.48 second-feet in a distance of 9,700 feet of channel. The average width was forty feet, giving an area of nine acres covered by the water. This corresponds to the loss of a layer of water 2.53 feet deep over the whole area of the canal. For half of this distance the canal extends along the sand bluffs which line the west side of Bijou creek, and is from thirty to ten feet above the channel of the creek. It is in a compact material, some of which needed to be blasted in constructing the channel. On the east side of the creek, it passes through a loose sandy soil, which slopes about one per cent. toward the creek. From evidence since obtained from the canal superintendent, Mr. Dingman, it seems probable that the loss from the west side is small or is insensible. A hole bored under the channel, and within a few inches of the water, was perfectly dry. If the loss is from the east side only, the rate must by twice as great as if from both sides, or would correspond to a layer five feet in depth per day over this portion of the canal. This would correspond to a velocity through the sand of about fifteen feet per day.

§ 42. On the Hoover ditch, running at the base of sandy bluffs, but with the bottom of the ditch covered with a fine silt, the loss in a distance of 1,500 feet was at the rate of 1.2 feet in depth for twenty-four hours, or a velocity of 3.6 feet per day through the sand.

§ 43. On the Muzza canal, in Italy, the loss is equivalent to a layer 1.7 feet deep per 24 hours. The canal runs through an exceedingly pervious soil, and has a great fall.

The Naviglio Grande, of Italy, loses a layer of water ten inches deep. The Canale Martesana, a layer 1.5 feet deep daily. The three canals above mentioned have been built for some 700 years.

The Centreville and Kingsburg canal, in California, from data given by C. E. Grunsky, of San Francisco, loses an average of five feet in depth, for six miles, in twenty-four hours. In one particular mile, where the loss is excessive, because of porous soil as well as from the location of the canal, near the edge of a bluff, the daily loss amounts to a layer fifteen feet in depth. This is an extreme case.* Another case of a great loss occurred in the Cavour canal, of Italy, at the crossing of the Dora river. This was by an artificial embankment. At first the loss amounted to a layer nearly twenty feet in depth. This was afterward very much reduced by using muddy water and allowing the silt to settle, and fill and cover the surface.

If we consider that in each of these cases the water occupies one-third of the volume of the sand, the distance it flows in twenty-four hours would be three times the thickness of the layers noted above, or from 2.5 feet on the Naviglio Grande to 60 feet in the Cavour instance.

It may be said, in passing, that the amount of loss from the canals may be much reduced by the settlement of fine clay or sediment. In one case, in the Cache a la Poudre Canal No. 2, where the seepage had made a considerable area so wet as to be impassable with teams, a check built for other purposes, by causing the deposition of silt, was sufficient in a few years to lessen the seepage so that the land became passable.

Another instance, illustrating the same effect, was shown in a canal near Greeley. When first built, considerable damage was done from the raising of the ground water and flooding cellars in some parts of town. After a few years the cause of complaint disappeared, silt sealing the bottom of the canal. In 1895 sand was obtained from the bottom of the ditch, where the ditch crossed a ravine, and where there was a good deposit of sand suitable for building purposes. The top layers of the sand were partially cemented. Within a few months after water was turned in complaint arose regarding the influx of water into the cellars. Ten days after the water was turned out of the canal, the water began to

*Since the above was in type, additional data, obtained through the courtesy of Mr. Grunsky, indicate losses of depths of 1.5, 1.7, and .6 feet, from stretches of the Kings River and Fresno canal; of 2.8, .25, and .4 from portions of the Fresno canal, and 1.2, 1.9, 3, 7 and 6.4 feet from certain laterals, the velocity through the soil being about three times as great.

go down in the cellars, falling about six inches in three weeks, and eighteen inches in a little over two months. A measurement of the amount of water in the ditch was made October 16, at the time of gaging the river, both above and below the point where the great loss was suspected. The quantity in the canal decreased from 25.86 cubic feet per second above the place, to 20.80 a little distance below, or a loss of 5.06 cubic feet per second. The total distance between the two measurements was forty-six rods. The total area of water surface was not noted, but with the increased breadth of the canal at the ravine crossing it is about one-half an acre. This would be equivalent to a depth of twenty feet, over the area wetted by the canal, in twenty-four hours.

SOURCE OF THE INCREASE.

§ 44. Whether the water forming this increase to the streams comes from the rainfall or from the waters applied in irrigation, is important to determine if possible. From the nature of the case, it is not possible to indentify the water, but a comparison of the increase between different regions of greater or less irrigation gives some basis for a conclusion. If the increase is partially or wholly from irrigation, it follows that the inflow will increase from year to year, as the amount of irrigation increases; that the lower reaches of streams will have a more regular supply; that the increase will show itself farther down stream, making it possible to gradually bring more land under cultivation; that many of the dry streams will become living ones; and that the damage which riparian owners in this and other States have claimed to be done by irrigation on the upper portions of the rivers will become less as time proceeds. If the inflow comes from and is due to the rainfall, then we cannot look for benefits of this kind, and those on the lower reaches cannot hope for a future lessening of the damages.

§ 45. Such gradual increase of the streams is common in countries with considerable rainfall, but the size of the streams and the invisibility of the small sources serve to mask it. The lack of measurements prevents the fact from being noticed. The rainfall in Colorado averages less than fourteen inches per annum. With this amount of rainfall, or with the rainfall of exceptional years, would there be any return to the stream without irrigation?

§ 46. There was no observation of the phenomenon before irrigation was practiced. But neither was there settlement. Irrigation was practiced for some years on the bottom lands before the use of water was sufficient to dry the stream bed, and thus make it possible to notice a small inflow, either by its effect on the volume of the stream, or by exposing the points of inflow. If there was any such inflow, it certainly was not sufficient to prevent the Platte from going dry in 1863 and other years. At the time of the first

measurement of the Poudre by Col. Nettleton, in 1887, the increase amounted to eighty-seven cubic feet per second.

§ 47. Where there is abundant rainfall, there is no question but that it furnishes a supply to the streams through underground passages, with effects similar to those noticed in the measurements of these streams. The amount which thus percolates through the ground is the portion of rainfall remaining after the run-off and the evaporation have been supplied. We have no direct observations under our conditions to determine positively how much, if any, of the rainfall remains to supply the underground water of the soil. Lawes & Gilbert, of Rothamstead, have maintained a series of drainage gages for a number of years. In the twenty-two years, from 1871 to 1892, fifteen to sixteen inches of the rainfall passed through forty to sixty inches of soil, and joined the subsoil water. This would be available for springs, and doubtless largely increased the volume of the streams draining the country. This was out of a total rainfall averaging 29.95 inches. Hence it follows that some thirteen inches in the humid atmosphere of England was required for evaporation from the surface of the soil, which was left uncropped and free from vegetation.

§ 48. With a smaller rainfall, it is not probable that the evaporation would be less. The greater dryness of our climate, the greater amount and intensity of the sunshine, which heats the surface of the soil intensely, are conditions which favor evaporation. The uniform dry condition of the soil shows that there is none too much for the evaporation alone. Our average rainfall is but little more than the amount which was evaporated from the soil in England, and some of this runs directly to the streams. It does not seem probable that there can be any left for percolation into the subsoil, except under unusual circumstances. In 1895, when eighteen inches of rain fell, not much more than usual was available for evaporation and percolation, since with the heavier showers a larger proportion runs off.

That the inflow comes almost entirely from irrigation is shown indirectly by the well-known effect of irrigation upon the height of water in the ground. Before irrigation, the distance to water is generally great, and the quantity frequently scanty. The application of water in large quantities to the surface, as in irrigation, fills the subsoil when porous, and raises the level of the ground water as much as forty to sixty feet in some cases. This establishes a steeper grade to the surface of the water in the soil, and gives the conditions which causes the water to pass through the ground with greater rapidity, and also with larger cross-section, thus increasing the amount of flow from both causes. The great distance to the ground water before irrigation, the scanty supply, the low grade of its surface, would in itself show that the amount received from the nat-

ural rainfall is small, and if this furnishes any inflow at all to the streams, it must be but a small proportion of the amount at present furnished under the conditions introduced by irrigation.

§ 49. From the mountain water-shed of the Poudre river our observations show that from four to six inches of water runs off from the whole area during the course of the year.* From the plains included in the measurements reliable observations are lacking. From the curve shown, by F. H. Newell, in the report of the U. S. Geological Survey for 1892-3, the amount of run-off may be estimated as from two to four inches. The amount varies with the soil, the slope of the ground, and the character of the rainfall.

When the precipitation is in slight showers, nearly all the rainfall evaporates within a short time, without penetrating more than the surface of the soil. It requires a heavy rain to saturate more than the surface, and furnish some water for percolation. In the ordinary condition, a rainfall of two inches will penetrate not over ten or twelve inches. Heavier rainfalls within a short time are needed before there can be any percolation from the rain. On beds of pure sand most of the water immediately soaks in, and very little is lost either by evaporation or by run-off, hence it is that water is generally found at moderate distances from the surface in the sand hills. There have been but twenty-two months in eleven years of observation at Fort Collins in which the total rainfall in one month has exceeded two inches, and in only eleven cases has as much as this fallen in one week. If the rain falls rapidly a larger proportion runs off than when there is time to soak into the ground. The case most favorable to percolation which our records show is in 1895, when two rainfalls, each of 2.5 inches, followed each other with only a few days interval. The first one nearly all soaked into the ground. The second fell on a ground already saturated and nearly all ran off, causing unusually high water in the streams in consequence. There are only one or two other cases in which as much as three inches fell within a few days. But even here, the most favorable of the cases, if the ground is dry, which is its ordinary condition, there cannot be much percolation, and it is very doubtful if there is any.

If, however, the ground is already wet, as may be the case with the lands which have been irrigated, and the surface is loose and porous so as to absorb the rain as it falls, as is the case with cultivated lands, there is reason to expect that the rain will cause an increase in the underground flow. The rainfall alone, without the irrigation, would not cause it, and it is a consequence of the artificial conditions introduced by irrigation, and may properly be considered as due to irrigation. A portion of the unusual increase

*Annual reports, 1890, 1891, etc.

found in 1895 is probably due to this cause. The inflow for 1895 was sixty second-feet more than the average. The rainfall was over four inches more than the average. Yet the extra sixty feet throughout the year would be given by a depth of one inch over 40,000 acres. If this comes from the rainfall, we must conclude that but very little of the extra rainfall was effective. As irrigation water is applied more freely because the supply in the river is greater, it seems more probable that the larger amount is due rather to the more water used than directly to the greater rainfall, though at present the effects cannot be entirely separated.

§ 50. Direct evidence bearing on the question was sought in the Platte measurement of 1894, but with negative results. If there be any substantial increase from such source, then the channels which conduct the drainage from a large area should show some indications of it. There are a number of such channels leading into the Platte, each of which drains over 1,000 square miles. This is more than the mountain water-shed of the Poudre river above its exit from the mountains. As the surface of the rock or impermeable surface has the same undulations as the surface of the ground, the underground drainage must follow essentially the same lines of drainage as the surface. This is shown plainly in the excellent sections taken at various points across the plains by Col. Nettleton and Mr. Follett.* One of these sections was across the valley of the Platte at Sterling.

The streams following these drainage lines, while permanent near their upper ends, are almost never flowing near their outlets into the Platte. It has generally been believed that these streams furnish much water to the Platte through the sand of their beds, and it has been a favorite article of belief among the adherents in the underflow idea. If this be the case, it ought to be shown by taking a measurement of the river above the mouth of the stream and below, far enough apart to include the bed of sand forming the channel. Even if the increase is not noticeably great, the rate of increase might well be expected to be greater than for the average of the stream.

§ 51. In order to test the question, I instructed the observers, in 1894, to measure the river above the important drainage channels, and also below. This was done by Messrs. Trimble and Preston, with the results shown in the detailed tables, and brought together in Table X. In most cases the channel spreads out into the bottoms of the Platte, so that it is sometimes necessary to make the measurements several miles apart, in order to include the expected inflow.

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* Reports Artesian and Underflow Investigation, 1890-1, 1892, U. S. Department Agriculture.

At the time an estimate based on the flow through the sands and the amount which might be expected, had not been made, and the results were so much less than had been expected—in some cases, in fact, showing an actual loss—that it seemed advisable to secure the measurements of another year, to confirm or disprove the results, before reporting them. In 1894 the volume of the river was so small that the errors in the measurement should be small. In 1895 the volume of the river was so great that plans had to be changed, and the number of measurements reduced. Enough, however, were taken to confirm the essential accuracy of those of 1894, and a personal inspection of the channels, with this in mind, indicates that at the best the increase from such sources must be small.

§ 52. The number of cases in which there is a loss instead of a gain is striking; and even granting that there is no increase from these streams, a loss was not expected. It may be said that the second measurement has been taken too near the outlet to catch the underground flow. In most cases this is not the case. The topographical features—the narrowing of the bluffs or some other feature—usually guided the choice of the second point. The map and the detailed tables of the 1894 and 1895 measurements will give a fair chance to make an independent comparison. In the case of the Bijou, the second gaging in 1894 was taken near the head of the Platte & Beaver canal but a short ways below the Bijou. In 1895 it was taken over a mile lower down the stream, and where the bottoms were narrow. A third point of measurement was taken in 1894 at the head of the Platte & Beaver supply ditch. Comparing the gain between the point above the Bijou and this place, we find a slight gain, but it is still less than the average of the river. There is very little irrigated area draining into this section, and it is especially little between the first and second points of measurement. There is some loss for the whole distance from evaporation, but during the time of these measurements it is difficult to account for a loss of more than one cubic foot per second per mile from this cause. It has been suggested that these loses are due to the varying depths of the bed of sand under the Platte, and the nearness of the bed rock in places. There is evidence that the thickness of the layer of sand varies, but definite data is lacking. If this be the cause of the loss, it would suggest that the bed of the Platte is washed out below the entrances of most of the streams, or else is filled with a coarser and more porous sand. The gain due to the nearness of the rock in some places should correspond to the loss at other places. At the measurement above the Bijou creek, there is a reef of rock. It shows for most of the width of the stream, and, at any rate, leaves only a small channel of sand. The gain, however, while more than in many other places, has not been marked enough to give great weight to this cause.

The question needs to be left open for future information. But the result, however, shows that the gain from the natural underground drainage cannot be much at best, and is probably nothing, at least too small to be measured.

The rainfall given in Table X. as the average for the given water-shed is derived from observations taken at stations on or close to the water-shed. It may be considered as a fair average of the amount falling upon the area draining into the channel. As the stations are few in number and the records not complete, the amounts are approximations of varying degree of reliability.

The drainage areas have been determined with a planimeter by measuring the area tributary to each stream from a map published by the Post-Office Department. They show the extent of the area tributary through these dry streams. Were the run-off in the course of a year equivalent to a depth of only 1.4 inches over the water-shed, each 1,000 square miles would give an average flow of 100 cubic feet per second; or, a run-off of a depth of one inch in a year, from the basin of the Bijou, would give a constant discharge of 100 cubic feet per second.

A calculation by aid of Table IX. shows that the amount derived from the inflow from these streams must be small. The breadth and depth of the beds of sand are unknown. If we assume a bed 80 rods wide and 1 thick, or an area in cross-section of one-half acre, and a fall of thirty feet per mile, then from Table IX. the velocity may be expected to be from 2 to 8 feet in 24 hours. As this is the flow through the interstices of the soil, which are one-third only of the section of the sand layer, the whole amount corresponds to from 1 to 4 acre-feet in 24 hours, or to a constant flow of less than 2 cubic feet per second.

It is not surprising that the measurements do not show any decided gain from such sources.

TABLE X.

INCREASE OF RIVER AT MOUTHS OF STREAMS.

(The negative sign indicates a loss.)

	Drainage Area. Square Miles.	Average Rainfall. Inches.	Gain of Platte, 1894. Second-feet.	No. of Miles Between Measurements.	Gain per Mile, 1894.	Gain of Platte, 1895.	No. of Miles Between Measurements.	Gain per Mile. 1895.
Box Elder creek	627	12.7	—51.05	3	—17.02	— 35.27	4.5	—8
Crow "	1,443	11.5	....	....	....	....	....	....
Lone Tree "	536	11.5	12.16	1.5	8.11	114.2	3.5	33
Lost "	390	....	....	....	....	....	....	....
Kiowa "	470	16.3	5.26	3.	1.72	—34.16	9	—3.8
Bijou "	1,425	14.5	—45.43	2.8	—16.2	—3.97	4	—1.00
	....	....	5.92	9.8	0.60	...	....	....
Pawnee "	600	....	3.52	1.75	2.01	....	....	....
Cedar "	514	....	9.71	1.5	6.5	....	....	....
Lodge Pole "	2,500	13.4	....	....	....	—47.6	9.5	—5.01

§ 53. The fact that, as a whole, the gain is small is a striking one, and even more so that there is in so many places an actual loss.

It, then, seems true that the amount of inflow brought down by these sands is much less than has been believed.

It seems difficult to account for as great losses at such points as is shown by some of the measurements, although the loss can be but little.

§ 54. We have not been able to secure enough detailed information of the location of the irrigated lands along the Platte, to be able to make a comparison in detail of the inflow and the irrigated area. The areas irrigated stretch along the Platte, usually near the river. The area watered near Fort Morgan is, perhaps, the most extensive, and farther from the river than the others. The number of acres which are tributary to each portion is not known closely enough to state in acres. But, making a general comparison, we have the following table. The most that can be said from it is, that the amount of increase bears a relation, in a general way, to the extent irrigated.

§ 54. Comparing the distribution of the inflow on the South Platte river with the irrigated lands, taking the average inflow as given in Table V., the average inflow to the State line is 2 feet per mile.

TABLE XI.

	No. of Miles.	Average Increase.	REMARKS.
From mouth of Poudre to Hardin ditch..........	8	62.0	Receives seepage from about 10,000 or 12,000 acres watered from Poudre, also from Upper Platte.
From Hardin ditch to Putnam ditch..................	11	17.2	Little irrigation — Hardin, Illinois and Corona ditches.
From Putnam ditch to Fort Morgan canal	14	57.8	Putnum ditch ; large part of Weldon Valley canal.
From Fort Morgan canal to Platte & Beaver canal.......	11	46.6	Most of Fort Morgan canal, remainder of Weldon Valley, Deuel & Snyder, and Pyott.
From Platte & Beaver canal to Snyder	14	49.9	Part of Fort Morgan canal, Platte & Beaver canal, most of Platte & Beaver supply.
From Snyder to Merino.......	18	55.4	Some of P. & B. supply ditch, P. & B., and Fort Morgan canal; most of South Platte ditch, all of Edwards and Johnson, Snyder, and Tetsel ditches.
From Merino to Sterling......	14	33.7	Large part of Pawnee, Springdale ditches, and other Sterling ditches.
From Sterling to Iliff.........	9	17.7	Remainder of the Sterling group.
From Iliff to Crook	17	20.3	The Iliff ditch.
From Crook to State line.....	36	21.3	Almost no irrigation.
Total gain...............	149	298.7	

EFFECT OF IRRIGATION ON THE UPPER PORTIONS OF THE STREAM.

§ 55. A question which arises in connection with the application of water and which has been warmly disputed, is as to the effect on the lower stream of irrigation on the upper portions of a stream. In the way in which land has been brought under cultivation, it has happened in most cases that lands along the lower portions of the stream have been settled, while lands above have later been brought under cultivation. It follows then that these latter lands will often see the water go by to supply those others which were first improved. In some places it has been contended that the application of water to the upper lands is an actual benefit to the lower lands, and in some cases the contention has been partially granted.

It is evident that the water which returns to the stream returns slowly. It returns sooner when the distance is short and the gravel is coarse. The volume of the stream fluctuates between wide limits, while the effect of passing through the ground is to even the flow, and hold the water until later in the season. Usually the streams are high early in the season, and in June have more water than can be used; they are low in August. If this retention by the upper lands is such as to diminish the height in June and increase the amount in August, the result is evidently a benefit. As the effect of the subtraction of the water from the stream is immediate, while the return is slow, the abstraction of water in low stages will be felt more than the return from the seepage. Hence, for a portion of the time at least, it seems that the use of water on the gravelly plains of the upper parts of our streams will be a benefit to the lower portions, irrespective of the date of their respective rights. Just when the effect of the direct diversion is greater than that of the return could be told by investigation in the particular cases, but would manifestly vary according to the circumstances.

There has been a tacit acknowledgment of benefit of irrigation on the upper portions of the stream in some of the water districts of this State in the fact that the upper ditches have been permitted to withdraw water without interference from the Commissioners or from the ditches with earlier rights. This has doubtless been partly due to the fact that the amount used by them is small. But some weight has been given to the claim that irrigation on the upper grounds stored water which entered the river in other parts of the year, when it was more useful to the lower ditches. The question will doubtless arise in specific cases in this State and others. The length of time during the season when such irrigation will not be injurious to the later rights, can be told by special gagings carried on throughout the year, on the plan followed by Vigan.

WILL THIS INVESTIGATION APPLY TO OTHER VALLEYS?

§ 56. In the valleys here measured irrigation has been practiced for thirty-five years; to a small extent on the bottoms for twenty or twenty-five years, and extensively for fifteen years. In the case of the Poudre, the lands are some of them twelve or fifteen miles from the stream. On the Platte, they occupy a much narrower strip. The conditions of the subsoil, the amount of water applied, the dip of the impermeable stratum of clay or rocks, the coarseness of the gravel, all affect the time and amount of the return. But given time enough, it seems probable that these results will apply closely to other valleys as well. A certain amount of water is required by the crops for the purposes of growth. In round numbers, 300 to 350 pounds of water is used for every single pound of dry matter produced. On some soils it is possible by skillful irrigation to apply but little more than is required by the crop and evaporated from the soil. Under such economy, there is little water which can pass away by percolation. To the economical irrigation induced by scanty and high-priced water is due the little or no return water noticed in Southern California. This is also influenced by the relatively small acreage. The narrow strip of the lower Platte and the more copious irrigation explain partially, if not entirely, the larger amount returned to the stream per acre, while the remote places of application on the lands of the tributaries of the Upper Platte shows a reason why the inflow there is relatively less. These may not completely explain the difference. Time, and added observations, will be needed to determine.

The same or similar phenomena have been observed to some extent elsewhere.

" When the Ganges canal was constructed, the whole available " cold season supply was taken from the river, yet at a distance of " only a few miles the discharge in the river was found to be very " considerable, and further on it increased to such an extent that the " supply taken by the canal was found to be little missed." *

§ 57. In Italy the effect of irrigation does not seem to have been noticed in the rivers, but principally in the large number of springs to which irrigation seems to give rise, and which are developed by digging in Lombardy and other provinces, and which the geological conditions do not seem to be sufficient to account for. ||

The losses from canals is well known, and the damages caused to neighboring lands by the seepage is a fruitful source of suits at law. In the contract of the Cavour canal with the Sesia Associa-

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*H. G. McKinney, Irrigation in Upper India, paper before the Royal Society, New South Wales, 1883.

|| Cagnassi, Irrigazione nella Provincia di Novara.

tion, for instance, the association becomes responsible for all damages from this cause.

§ 58. "I am inclined to think that the seepage is much "greater and of more importance in Colorado than anywhere in "California, for, while I know that such percolation does exist in "various places in the irrigated districts, I cannot recall a single "place where it takes place in any such volume as in your country. "The Santa Ana river is affected by seepage from Riverside and "San Bernardino valley, so that the volume of supply for the "Anaheim and Orange canals below is rather increasing than "diminishing, but the extent of this return is conjectural." †

"Some years ago the people owning water rights along the "lower parts of our mountain streams imagined that the use of the "water by parties located some distance above them would seriously "interfere with their water rights and prove very injurious to the "land below. Experience has proved that this fear was groundless "to a large extent. Indeed, it is now found that a large use of water "in the early summer on the upper lands insures a more plentiful "supply in late summer for the lower lands." ‡

Hon. Geo. P. Marsh, for a long time our minister to Italy, in *The Earth as Modified by Human Action*, in commenting on the results of Vigan (§ 59) states that it is generally estimated that from one-third to one-half of the water applied to the fields is absorbed by the earth, and this, with deduction of the amount evaporated, absorbed by vegetation, and entering into new organic compounds, returns to the streams or descends to greater depths. In Colorado a much smaller proportion of the water applied runs off and a much larger proportion is absorbed, as the system of wet meadows, or *marcite* and rice irrigation, does not prevail in Colorado. The measurements on the Poudre indicate that at least 30 per cent. of the water taken from the river returns through the seepage. If water is applied as freely until the seepage from the outer lands reaches the river, the amount of return waters will be greater than this amount.

OTHER INVESTIGATIONS.

§ 59. The phenomenon of return waters has been apparently but little noticed and less written upon. It was the subject of an investigation by the government engineers of France some thirty years ago in the valley of the Tet,* in southeastern France, where the question became important, as it is in some places in Colorado, in the dispute between water users of the lower valleys and those of

† Manuscript letter from J. D. Schuyler, Consulting Engineer, Los Angeles, California.

‡ Extract from manuscript letter from President Geo. Q. Cannon, of Utah.

* Vigan, Annales des Ponts et Chaussees, 1867.

the upper portions of the stream. The earlier canals, some built by the Moors before 1000, A D., were taken out from the lower portions of the stream, the later ditches near the head.

The lower canals desired to close the upper ones. The latter claimed that the water that was applied by them in irrigation returned to the river to a great extent, and thus had the effect of making the stream more constant in its flow, and, therefore, was as a whole advantageous for the lower users. During several years a system of measurements was carried on at different places on the stream and included all the water that came into the stream through the smaller tributaries. Measurements were made daily by the local officers. The valley is one the total length of which is something like fifty or sixty miles, and the total area irrigated is 32,000 acres. The cultivation consists largely of wheat, beans, alfalfa, meadows, and gardens, with small quantities of potatoes and flax. A biennial rotation is practiced which dates from the Moors. Grain is usually watered three times, once at the time of sowing, in November. Irrigation is practiced throughout the whole season. In the upper valley wheat is not watered. Beans are watered from the middle of July to the middle of September. From the data obtained, M. Vigan reached the following conclusions: The return waters are derived from all irrigated lands of the valley, varying according to the crops, amount of water used in each season, thickness of the soil, its composition, and the slope of the impermeable layer. He concludes that, in the bottom lands, which form a bed about a mile wide along the stream, and are abundantly watered, from the first of March, that the return waters from this source are sufficient to compensate for the losses caused by irrigation during the greatest part of the low water. He also concludes that, in the area forming a strip two or three miles wide, with a very deep layer of permeable soil, the return waters come to the surface only in some places; that the greatest part of the springs which are caused flow unused in the subsoil and return frequently to the sea. On these lands irrigation occasions considerable loss; hence he concludes that, in case of an application for water right in the stream for canals, or ditches, which are to be newly constructed, the concession should be refused, except conditionally. In case water is lacking in the other canals, then the new ones should be closed. In general, under the conditions existing in that valley of the Tet, irrigation at the upper portions of the stream with water taken at periods of high water, is beneficial to the lower portions of the stream. The water thus applied gradually returns to the stream in such quantity that the stream is not so low as if the irrigation had not been practiced.

Some of the measurements of the Poudre river have been given in the Colorado Agricultural Experiment Station Report, 1891, p. 45-50.

Also see reports of the State Engineer of Colorado, 1885-6, p. 205-208; 1889-90, p. 559-570; 1891-92, p. 51-65; 1893-4, p. 176-192.

In bulletin No. 38, of Utah Experiment Station, Prof. Fortier has given some measurements for one year, showing the amount on some Utah streams, and leading to essentially the same conclusions as Vigan. Prof. Fortier's study is a valuable contribution to the subject.

A discussion by Senator David Boyd of the applicability to the Arkansas valley of conclusions from the Platte measurements, occupies part of a report of a special committee on the State Canal No. 1, Tenth General Assembly, p. 40-49.

In the Annales des Ponts et Chaussees, 1883, p. 34-60, M. Bazaine has a study on *L'Influence des Irrigations sur l'Altitude d'une nappe souterraine* occasioned by the observations of the effect of irrigation from the sewage of Paris on the ground water of the sewage farms of Gennevilliers. It has little application to the present discussion, except as it deduces the equation of the surface of the underground water, which is parabolic.

CONCLUSIONS.

We may draw the following conclusions from the observations and considerations shown. The facts are presented in sufficient detail to show the bases of these conclusions, or to enable independent conclusions to be reached, if the reader so desires:

1. There is a real increase in the volume of the streams as they pass through the irrigated sections.

2. There is no such increase in the streams as they pass through the unirrigated sections. On the contrary, there is an actual loss, even when the drainage of a large area enters.

3. The increase is more as the irrigated area is greater.

4. The increase is approximately proportional to the irrigated area, and it seems probable that with more intimate knowledge of the amount of water applied and the features of the drainage, the proportions would be found to be close.

5. The amount of the increase depends very slightly, if at all, upon the rainfall, and, so far as it does, it is influenced principally by the rainfall on the irrigated lands. Only where the lands are already saturated, is the rainfall sufficient to cause seepage.

6. There is no perceptible underflow from the side channels, even where they drain several thousand square miles.

7. The inflow is practically the same throughout the year. It is more in summer, less in winter, principally because of the effect of the temperature of the soil.

8. The passage of the seepage water through the soil is very slow, so that it may take years for the seepage from the outlying lands to reach the river.

9. The amount of seepage is slowly, but constantly, increasing.

10. It may be expected to increase for some years to come.

11. An increased amount of land may be bought under cultivation, with time, more especially on the lower portions of the streams.

12. The seepage being nearly constant throughout the year, while the needs are greatest in summer, the use of storage will best utilize the water from inflow.

13. The seepage from one thousand acres of irrigated land on the Poudre river gives one cubic foot per second constant flow; on the Upper Platte, one foot to about 430 acres; on the Lower Platte, one foot to 250 acres. The difference is due mostly to the greater distance for the seepage to reach the main stream, and to the time and amount of water applied.

14. One cubic foot per second of inflow is obtained on the Poudre river for each 2,400 acre-feet applied, or the inflow is about one-third as much as the water applied.

15. On the Poudre river about 30 per cent. of the water applied in irrigation returned to the river.

16. The use of water on the upper portions of a stream, when water is not immediately needed by prior appropriators, will increase the flow of the stream late in summer and prevent such low stages as it would have without this regulating action.

17. The seepage water is already an important factor in the water supply for the agriculture of the State. The capital value of the water thus received in the valley of the Cache a la Poudre alone is not less than $300,000, and perhaps $500,000, and for the Platte is from $2,000,000 to $3,000,000. It is large for the other streams, but of unknown amount.

18. An actual loss is incurred in carrying a stream like the Platte through sandy beds.

19. Ultimately, the returns from seepage will make the lower portions of such valleys as the Platte more certain of water, and probably enable a larger acreage to be grown.

20. The results here shown may be expected to apply with limitations to other valleys similarly situated, where irrigation is

as copious, crops the same in character, subsoil and rock strata of much the same inclination. Where the soil is less pervious, a greater time must elapse for these results to hold good.

21. Measurements are greatly needed in the Arkansas and Rio Grande valleys, for the determination of facts which will soon become of importance. In the Rio Grande, especially, because of the claims made by Mexico that irrigation in Colorado is proving an injury to her people and infringing privileges guaranteed them by treaty. If the results of this investigation apply to the Rio Grande, then any injury must be largely compensated by the return, and the greater regularity in the flow produced in the river.

ACKNOWLEDGMENTS.

§ 61. Information and aid to a greater or less extent has been received from too many to mention. To the various Water Commissioners, especially to J. L. Armstrong and R. Q. Tenney, of District No. 3, and J. T. Hurley and R. J. Patterson, of Nos. 1 and 64, our thanks are especially due.

By the kindness of G. H. West and D. A. Camfield, of Greeley, a team was furnished us for the measurement of the Platte, in 1895, and we are indebted to Receiver Trumbull, of the Union Pacific & Gulf Railway, for transportation where necessary during the measurements.

The diagrams have been drawn by Mr. J. D. Stannard, who has also aided the laborious work of reduction of the observations; Mr. Trimble has also aided extensively in the same work, and in the field work, as noted in the detailed observations, and also in preparing and checking the tables.

Through oversight, credit was not given, on page 32, in a part of the edition, to Mr. P. J. Preston, for Measurement No. 5, made under direction of the State Engineer.

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Cattle Feeding in Colorado.

Approved by the Station Council,
ALSTON ELLIS, President.

FORT COLLINS, COLORADO.
MAY, 1896.

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Cattle Feeding in Colorado.

Colorado is pre-eminently a grazing state. Few crops can be raised without irrigation, and the total irrigated area of the State is about 2,000,000 acres, or one acre in about every thirty-three. The remainder of the State can be used for nothing but grazing.

Part of the land is occupied by sheep, especially in the south middle portion of the State. Most of the counties east of the mountains support some sheep. There is not much difference in the number of sheep and number of cattle, but the sheep require so much less land per head that the total area of the State occupied by cattle is much more than that used by sheep.

The cattle ranging districts are scattered over the entire State and with considerable uniformity. There are in round numbers about 700,000 cattle in the State. The earlier cattle of the western ranges were so-called native stock, such as is now raised on the ranges of Texas and New Mexico. Much of this is still on the ranges of the southern half of Colorado. The improved breeds have made more headway in the other half of the State, especially in North Park and Estes Park and the foothill and plains country from Boulder northward. The earlier importations were of Durham blood. This breed was found well adapted to the varied conditions of Colorado, whether on the plains, foothills, or elevated parks, and has been more used than all the other improved breeds together. The only other pure breed that has been largely used is the Hereford, or Whiteface, as it is commonly called here. This breed is especially adapted to hilly pastures and is probably fully as good as the Shorthorn for most Colorado ranges. Attempts have been made to bring in other breeds such as the Polled Angus, the Galloway, and the Red-polled. All feeders now recognize the advantage of having no horns on the cattle when they are put into the feeding corrals, and it was natural that they should attempt to raise cattle that would be hornless from birth. These polled cat-

tle have made but little headway in the State, the cattlemen preferring to stick to the Hereford and Shorthorn breeds and dehorn their stock.

RANGING AND WINTER FEEDING.

All the cattle of Colorado are ranged through the summer, and the greater part are also wintered on the range. But the free, open range in this State is a thing of the past. There was a time, but a few years ago, when the whole San Luis Valley, as large as a New England state, was one vast winter range for cattle. As many as 250,000 head have been driven from their summer ranges on the mountains to spend the winter in this valley.

But agriculture is superior to grazing, not only in this valley, but in all the valleys that can be irrigated east of the mountains. The cattle have been driven out by the plow. The cattle of the San Luis valley have shrunk to 60,000, though this decrease is partly due to the sheep overrunning some of the ranges formerly used by cattle.

With the advent of permanent settlers, a great change has come over the methods of ranging. Formerly, by mutual agreement of the cattlemen, certain favorable portions were set aside for winter range. But these favorable spots are the ones that would first be taken up by the settler, compelling each cattleman to look out for his own winter range. Fences have come in to keep cattle on the land where it is desired they should remain, or still more commonly, to keep them and other cattle out of the lands that are to be reserved for winter use. Drinking water is a necessity on all ranges. Temporary summer streams are common in the hills and on the plains, but permanent streams are scarce anywhere in Colorado. It did not take the cattlemen long to learn that if they controlled the water they held the key to the neighboring range. This is usually done by buying or leasing the sections or quarter-sections that include the permanent running streams and fencing them against all cattle but their own. This gives them free use of the range on both sides to the next water-shed. Five miles of stream can usually be controlled by leasing and buying not more than 1,500 acres of land, and give the cattleman the use, without cost, of an extra 10,000 to 20,000 acres. Often the owning or controlling of four quarter-sections at the mouth of a valley virtually controls the range of the whole valley. These conditions necessitate much smaller herds and a larger number of cattle owners than under the former system of the open, free ranges.

Most of the cattle of the State are now owned and run in bunches of 300 head or less.

The bane of the cattle business in Colorado, as elsewhere, is the cattle thief, or "rustler." If it were not for the danger of loss from this source, the cattle could be left to themselves most of the time through the summer, and, by the use of fences around the winter range, but little time would necessarily be devoted to them the rest of the year. But the rustler is omnipresent, and if it were known that nobody was looking out for any given herd, it would rapidly disappear. This necessity for riding the range nearly all the year largely increases the cost of running cattle, especially considering the small size of the bunches.

All degrees of winter feeding exist. There are few winter ranges so good that the animals will gain in weight during cold weather. The first frosts come in September, and from then until the new grass starts the next May, animals on the range do well if they hold their weight. This leaves but five months in the year for the animal to grow and seven months for it to stand still or even go backward.

It is evident that, if winter feed were good enough to keep the animal growing all the time, it would bring the animal to marketable size in a much shorter time. The present tendency of cattle raising is in this direction. A large number of cattle in the State are wintered on range feed mostly in the bottom land. A still larger number are fed through part of the winter on native hay cut along the streams. A smaller number are wintered on tame hay, largely timothy that has been sown for that purpose, and a still smaller number are brought out of the hills and parks to winter in the irrigated regions on alfalfa hay. The latter form is, of course, the most expensive and its advantage is merely a question of the amount of growth made as compared with the value of the hay eaten. But few cattle would be fed in the irrigated regions if alfalfa was their only feed. It happens, however, that, although the plow has destroyed the range, yet it has substituted the stubble fields. To utilize the stubble both of grain and of alfalfa and the straw of the grain, is the principal reason for wintering cattle in the irrigated regions. All this good feed material would otherwise be a total loss. Grain stubble and the straw that goes with it sells for winter feeding at from seventy to one hundred dollars per quarter-section. The cattle get considerable grain from the stubble and from the chaff at the straw stacks. It is not expected that cattle

wintered in this way will gain in weight, but it is a rather cheap way of carrying stock through the winter.

In whatever way stock are wintered, there are few feeders in the State that do not make some arrangement for giving their stock extra feed in cases of unusually severe storms. They thus reduce the risk of running cattle, and in the course of years greatly reduce the winter losses. When cattle were allowed to rustle for themselves, there was a profit in the business, on the average, because beef was high and summer feed cost nothing. But when the severe storms did come many a herd was almost wiped out of existence, and the owners ruined financially. Stock raising under such a system was gambling on the weather of the next winter. As the price of beef fell, the business could not stand such a heavy drain on its profits and the cattlemen either went out of the business or made provision for a more certain winter feed. The most trying time of the year for stock is the months of March, April, and May, when the stock, already weakened by wintering on scant rations, are turned off the stubble fields onto the summer ranges. The new grass is not yet sufficient to supply their wants, and late storms often do enormous damage. A stack or two of hay carried over until this time is often the most profitable crop of the year. Many farmers carry hay to the range, and the cattle soon learn where to go for fodder during storms.

The most economical winter feeding is that where the summer range is near the winter range, so that the cattle can be left as long as possible on the summer range and, when brought to the winter range, they are then near the place where the hay was cut. Under these conditions they can gather their own living, except in case of storms or deep snows. Hay is then fed without moving them from the range. The usual amount is ten pounds of hay per head per day. They may need to be fed but a couple of days, before the weather moderates, or this feeding may in extreme cases last continuously for months, as it did in the winter of 1894-95 on some ranges. The hay is fed scattered on the ground, cattlemen having found by experience that but little is thus wasted and there is a saving of the cost of racks and the considerable danger of accidents that come from the crowding and pushing of rack-fed cattle.

Straw can be profitably used as a large part of the food for cattle that are being fed through the winter. West of the main range in Colorado, where the number of cattle is large as compared with the land sown to grain, nearly all

the straw is so used. The same is true of the San Luis valley, which produces a large amount of straw, but also winters a great many cattle. On the plains east of the foothills there is more straw than cattle, and the surplus straw is usually burned.

MARKETING.

There is no definite age at which the old cows are sent to market. There have been times and places in the history of ranging cattle when the cows were never gathered, but allowed to remain on the range until they died of old age. The present custom is to gather up the farrow cows and sell them off in the fall, adding to them such heifers as prove barren and such old cows as seem to have passed their prime.

There is a wide difference in the age at which steers are sold for beef. Steers coming five years old used to be the standard beef cattle, and when they live all the year on the range with no extra winter feed they will scarcely get their growth in less time. By better care, more liberal winter feeding, with an infusion of the blood of the pure breeds, this time can be largely shortened. The general rule at the present time is, to sell as soon as they reach a live weight of a thousand pounds. If the steers have good enough winter feed so that they hold their own, they will reach this weight the fall after they are three years old. With a little better winter feed and better breeding they can reach the same weight at two years past. The steers that go to market from Colorado at the present time are about evenly divided between the two ages.

A few breeders of well-bred stock that feed liberally during the winter, are able to shorten the time still one year more and produce steers that will weigh a thousand pounds at twenty months old. It cannot be said that any one of these ages is the best, but the tendency of cattlemen is to feed better and market earlier. The younger the steers are sold, the more head can be kept on a given range, the smaller the investment, and the quicker the returns.

Most of the Colorado steers that are shipped out of the State are sold for feeders, that is, they are sold to Kansas and Nebraska men who feed them for three or four months on corn and then send them to the market for beef. Some of the steers are sold directly from the range, but the great bulk are fed on hay for two or three months and then go east for the grain feeding. The business of grain feeding these steers in Colorado is yet in its infancy, and opin-

ions differ as to whether it can with profit ever become the principal method of handling them. Colorado is not a corn state, and it looks reasonable that it should be cheaper to ship the steer to the corn producing districts rather than to ship the corn west to Colorado and then the fattened steers eastward. It has so far proved profitable to bring in corn for sheep feeding; but this success is largely due to the Colorado climate and the possession of large amounts of cheap alfalfa that cannot be fed to the sheep unless it is accompanied with grain. The problem with steers is somewhat different. Alfalfa alone can be fed to steers and they will make a reasonable growth. The question before the feeder is, whether, if grain is fed in addition, they will grow enough faster and sell for enough more per pound to pay for the grain and leave a fair margin of profit for the extra risk. Incidentally there comes in the additional fact that the alfalfa is raised on the farm, while the grain will usually have to be purchased with money advanced by the banks at a high rate of interest.

A few figures will show the conditions of the two methods of feeding. Steers are usually bought in the fall with a three per cent. shrink and sold in the spring with a four per cent. shrink. In the fall of 1895 cattle off the range, if of good quality, sold for about $2.85 per hundred pounds live weight. A 1,000-pound steer would therefore cost one thousand pounds, less three per cent. shrink, or 970 times $2.85, or $27.65. A good steer on hay alone should gain a pound a day in live weight. At the end of a hundred days' feeding, the steer would weigh 1,100 pounds and sell with a four per cent. shrink, or 1,056 pounds. The steer will have eaten and wasted about two tons of hay, so that if sold for one-half a cent a pound more than it cost, it would return $3.86 per ton for the hay. Each ten cents increase, or decrease, in the selling price makes a difference of fifty cents per ton in the amount realized for the hay.

When steers are grain fed to make beef of them they are fed the first sixty days on hay and the next ninety on hay and grain. The grain feeding in connection with alfalfa will seldom go higher than eight pounds of grain per day per head, and this maximum amount will be reached by the middle of the grain feeding period. This gives six hundred pounds of grain for each steer. The grain takes the place of some of the hay, so that in the whole five months, the steer eats and wastes about three tons of hay. The growth should average about a pound and a half a day for

the whole period, or two hundred and twenty-five pounds. At $15 per ton, the six hundred pounds of grain would cost $4.50 To return four dollars per ton for the hay, the steer will have to sell for ninety cents per one hundred pounds more than it cost. The question before the feeder is, therefore, whether the chances of grain fed cattle selling for ninety cents per hundred more than they cost, are greater or less than the chances of hay fed cattle advancing fifty cents per hundred more than their cost. This is a difficult question to answer. The average of the markets for several years makes the two systems about equal, and since the hay feeding involves the less risk, most Colorado feeders have adopted this method. On April 1, 1895, hay fed steers sold for $1.15 per hundred more than they cost off the range the October previous, while the following year the difference was but forty-five cents. The markets of these two years show that cattle feeding is largely a lottery. The final gain or loss depends primarily on the feeder being a good buyer, and getting stock that will fatten well at a fair price. After this he is at the mercy of the general tendency of the market. He may lose on his investment after careful feeding and good care, and the market may turn in his favor, as it did the winter of 1894-95, and give good returns to even poor feeders.

A question that greatly troubles all cattle feeders is, to know what is the best time to sell. It can be said in general that there is no "best" time. The week of highest prices one year may show the lowest prices the following year.

The consumption of cattle is fairly constant for the whole year, and the prices for the same grades of cattle do not differ to any great extent; but, owing to the influnce of supply and demand, the market is varying a little up and down all the time. Cattle are bought and fed on so narrow a margin that these small variations of twenty-five cents per hundred may make all the difference of gain or loss on the transaction.

It is in general true that the longer cattle are kept and fed the higher price per pound they will bring in the market. So long as there was a large demand for heavy cattle for export, there was almost no limit to the weight and fatness that could be put onto steers. Within the last few years a change has taken place in the wants of the market. There is a smaller demand for heavy, fat 1,600-pound steers, and an increasing demand for well fattened 1,100 to 1,300-pound animals. This change has been especially marked

during the winter of 1895-96, until now there is but little difference in the market value of the two classes. Indeed, the past season has witnessed several cases of the lighter steer selling for the higher price. Under such conditions there is no incentive for attempting to grow the big steer, and the most profitable transaction now is to market the steer as soon as he can be be gotten fat after he reaches a thousand pounds live weight.

COST OF RANGING CATTLE.

The cost of running cattle on the range varies from \$2 to \$4 per head per year, according to the conditions of range and the amount of winter feeding.

In the foothills and parks where some hay has to be provided for winter and enough land owned or leased by the cattleman to insure his winter range from intruders, one man can take care of about 300 head of cattle of all ages. He can also put up the seventy-five tons of hay that would be needed for winter with the aid of extra help for a few weeks. The present prices on the range are about \$15 per head for cows, \$12 for yearling steers, \$17 for two-year-old steers, and \$25 for three-year-old steers, making a mixed herd of 300 head worth about \$4,500. The value of the range, with what fences, corrals, tools, etc., that the cattleman would need, would be about \$2,000. The items of expense would therefore be as follows:

Wages of herder, 12 months @ \$30	\$360 00
Extra help in haying	20 00
Taxes @ 2½ per cent. on ½ the valuation	80 00
Total	\$460 00

This \$460 represents the cash outlay for herding 300 head for one year, or about \$1.50 per head. On some ranges, salt would need to be fed, some giving as high as twenty-five pounds per head per year. Some cattlemen have found it advantageous to keep a small amount of grain on hand to feed to weak cows and young calves in March and April. A ton of grain will usually be an abundance for the cows in a herd of 300 head. These two items of salt and grain would add twenty-five cents per head per year to the cost of ranging stock.

The above items are the ones in mind by the writers who claim that cattle can be run for less than \$2 per head per year. To make a complete statement there must be added the interest on the investment:

Int. on value of range, $2,000 @ 6 per cent..	$120 00
Int. on value of cattle, $4,500 at 6 per cent..	270 00
Total..............................	$390 00

The interest account is therefore about $1.25 per head, raising the total cost of ranging to $3 per head per year.

On the plains where the cattle can be run in larger herds, some of the items above would be lowered. But the extra expenses of the general round-up would be enough to bring the total cost to fully as much as the above estimate.

GROWTH AND LOSSES.

One of the first questions asked by a prospective cattleman is, What will there be for sale each year from the herd? This depends on two things, first, the per cent. of calves, and second, the per cent. of loss in the calves and in the older stock.

The number of calves dropped varies with the number and vigor of the bulls used, and the care taken by the herdsman to insure service. It is customary to keep one bull for each twenty-five cows. A larger per cent. of calves will be dropped if the bulls run in the herd all the time, but in this case so many calves come in the winter and die from exposure that more and stronger calves are raised by keeping the bulls away from the cows until summer, so that most of the calves will be dropped in the late spring. It is best that the heifers should not calve for the first time until they are fully three years old. If the bulls are kept away from the herd except in the fall about forty per cent. of the heifers will drop their first calves when two years old and the rest of them not until the next year. Under good conditions, there should be eighty calves dropped from each hundred cows in the herd, but the number of these that will be alive next spring is very variable. When the cattle are well cared for in the winter, and the herdsman is on duty all the year around, the herds in the foothills and parks ought not to lose more than five per cent. of their number each year. On the plains, it is customary to allow ten per cent. to cover losses. These losses occur through stealing, starvation, lightning, miring in bogs, spring colds, and accidents. Cattle are very apt to get mired in the spring by going on the swampy land after the first green grass, and they have so little strength at this season that they cannot release themselves. Much higher losses than the above sometimes occur. When the cows and their calves are left to take

care of themselves on the open range with no extra winter feed scarcely fifty per cent. will reach one year old. During the severe winter of 1894-95, four times the ordinary amount of hay was eaten by some herds, and others that were left on the range lost sixty per cent. of the whole herd.

Such losses, both in calves and older stock, used to be expected every four or five years by the cattlemen of Colorado from 1875 to 1885, and the business was so profitable that it could stand an average annual loss of twenty per cent. The margin of profits is now too small to take any chances, and by winter feeding the losses have been reduced to from five to ten per cent.

What will there be for sale each year from a mixed herd numbering 300 head? On the basis of there being eighty per cent. of calves dropped and an average of five per cent. of losses, a herd of 300 head will consist in the spring of:

Cows	55
Three-year-old heifers	37
Two-year-old heifers	39
One-year-old heifers	42
Three-year-old steers	39
Two-year-old steers	41
One-year-old steers	43
Bulls	4
Total	300

About forty per cent. of the two-year-old heifers would drop their first calves during the summer and these, with the calves from eighty per cent. of the three-year-old heifers and the same proportion of the older cows, will give a total of ninety calves, one-half of which would be steers and one-half heifer calves. As five per cent. of these would be lost, there would be on hand the next spring forty-two yearling heifers and the same number of yearling steers to take the place of those of the year before and keep the number good.

There would be the thirty-nine three-year-old steers for sale in the fall and some of the cows. How many cows should be sold would depend on the object of the breeder. If he wishes to enlarge his herd he would sell as few as possible. If he wishes to keep the herd constant at three hundred head, he would sell enough of the cows so that in the spring he would have the same number as the year before. On the average this would be about twenty-five.

For a herd on the plains, or anywhere that the annual losses amounted to ten per cent., a natural herd of three hundred head would be composed of:

Cows	70
Three-year-old heifers	31
Two-year-old heifers	36
One-year-old heifers	42
Three-year-old steers	36
Two-year-old steers	39
One-year-old steers	42
Bulls	4
Total	300

There would be ninety-six calves dropped during the season and thirty-six three-year-old steers for sale in the fall with twenty cows.

It is not to be expected that all herds will be made up of exactly these proportions. Even in a natural herd, that is, where all have been raised and none bought, the losses will vary from year to year, producing variations from these figures which represent averages for many years on many herds. The largest variations in herds are caused by buying in young stock, so that the herd has a disproportionately large number of steers compared with the cows. Or, the opposite condition comes from selling off in a single season more than the three-year-old steers. The former is the more common condition in the northern part of Colorado where many thousand young steers are brought in each year from the south and turned onto the ranges. The latter is common in southern Colorado and especially in New Mexico and Texas, where the steers are largely sold at one-year-old to go onto the northern ranges.

The estimate given shows an annual cost, not including interest, of about $500 for running a herd of 300 head. The yearly sales are about thirty-eight head of three-year-old steers and twenty-two farrow cows. The steers should bring $30 and the cows $15 per head, or a total income of $1,470. Deducting the $500 expenses, leaves net returns of $970, or about fifteen per cent. interest on the investment.

SHIPPING.

The people of Colorado eat 100,000 head of cattle every year. The larger part of these are old cows with a liberal sprinkling of barren heifers and a still smaller number of hay fed steers. Almost no grain fed cattle are con-

sumed by Colorado markets. The largest local market of Colorado is Denver, which buys as many steers as all the other markets of the State combined. The other principal market for Colorado cattle is Omaha. Very few steers are shipped directly from Colorado to Chicago, because as a usual thing they are not fat enough to bring a high price in that market. Quite a number of shipments from southern Colorado are made to Kansas City. From most of the shipping points in Colorado, cattle will reach Denver with forty pounds shrinkage in live weight; will sell at Omaha or Kansas City with a sixty-pound shrink, and will weigh in Chicago 100 pounds less than when they started in Colorado. When steers are sold at the farm an allowance of four per cent. is made, which is just about what the steer will shrink in going to Denver. If the steers are to be shipped to Denver, they must sell there for as much as they would on the farm plus the cost of freight, feed, commission, yardage, and expenses of the man who accompanies them. These items would be, per head, about fifteen cents for feed, fifty cents for commission, twenty-five cents for yardage, and about thirteen cents per hundred pounds for freight. The expenses of the attendant will hardly be less than fifty cents per head, making the total cost of marketing a 1,000-pound steer $2.20. To make any profit from shipping the steer, it must bring more than twenty-two cents per hundred pounds above the price that could be obtained on the farm.

If the shipment is to be continued to Omaha or Kansas City, there will need to be added about seventeen cents per hundred for freight, fifteen cents per head for feed, and another fifty cents per head for attendant's expenses. These, added to the twenty pounds more of shrinkage, require that the steer shall sell in Omaha or Kansas City for an advance of twenty-eight cents per hundred pounds to agree with the Denver price.

The expenses would be more from Omaha to Chicago than from Denver to Omaha, making a difference of about forty cents between these two markets. The costs of getting the steer from Denver to Chicago is, therefore, about sixty-eight cents per hundred pounds; from the farm to Omaha, about fifty cents; and from the farm to Chicago, ninety cents, these figures including the shrinkage. With these heavy expenses and the greater risk, it is no wonder that a large proportion of Colorado cattle are sold on the range or farm to professional cattle buyers, who are more experienced in the business.

Experiments in Feeding Steers at the College Farm.

During the winter of 1894-95, several experiments in steer feeding were carried out on the College farm. They included tests of different classes of steers and of various kinds or combinations of feeds.

Eighteen steers were fed, comprising three groups of six each. The first group consisted of six grade Durham steers, four years old that had been raised on a farm as skim-milk calves. They had been well fed and wintered, making large framed, well formed steers, of about 1,300 pounds weight. They were taken off good alfalfa stubble when bought and were in fair condition, but not at all fat. They were brought to the farm November 15th.

On December 6, six grade Polled Angus steers were purchased. They were late summer calves of the year before; being thus seventeen months old and averaged about 700 pounds, varying from 660 to 760 pounds. They had been hay fed during the winter and had been brought from the summer range to alfalfa stubble about the middle of November. A week later six more steers were purchased, being of the same general breeding and care as the first lot of four-year-olds, but two of them were nineteen months old and the other four, thirty-one months old. The yearlings weighed about 830 pounds, and the two-year-olds a little over 1,000 pounds each. These were also brought off alfalfa stubble. The eighteen steers, therefore, consisted of six four-year-olds, four two-year-olds, and eight yearlings.

The six four-year-old steers were fed cut alfalfa hay and cut corn stalks for the first twenty days, with the exception of two days on whole oat hay, which they did not like, and two days on whole alfalfa, which they ate fairly well. This same oat hay was afterwards cut up and fed to them and they ate it rather under protest. During the first thirty days they ate:

Alfalfa fed.....5,267 lbs., or 29 lbs. per head per day.
Corn stalks fed, 1,325 lbs., or 8 lbs. per head per day.

Total fed..6,592 lbs., or 37 lbs. per head per day.
Refuse.... 617 lbs.

Total eaten, 5,975 lbs., or 33 lbs. per head per day.

This thirty-three pounds eaten per head per day consisted of about twenty-seven pounds of alfalfa and six pounds of corn stalks. Of this feed the steers gained about a pound per head per day.

The black steers were put at once on cut alfalfa and in the nine days from December 6, to 13, they ate 945 pounds, or seventeen pounds per day per head.

When the third lot of steers came, December 15, all three lots were put on the same cut alfalfa, and in the four days from then until December 19 they ate as follows:

FEEDING RECORD, DECEMBER 15–19.

	Average Age, Years.	Average Weight, lbs.	Alfalfa Hay Eaten, lbs.	Hay per Head per day. lbs.
Four-year-olds	4.6	1274	764	32
Two-year-olds	2.3	967	504	21
Yearlings	1.4	703	465	19
Average	2.8	981	578	24

On December 19, the four-year-olds were changed to whole alfalfa hay instead of cut, the rest still having the cut hay, and all from the same lot of hay as before.

FEEDING RECORD, DECEMBER 19–27.

	Average Weight.	Hay Eaten.	Hay Eaten per Head per Day.	Hay eaten per day per 1,000 lbs. weight.	Gain per head per day, Dec. 12 to 27.	Hay Eaten per Pound of Growth.
Four-year-olds	1289	1749	36	27.8	1.0	36
Two-year-olds	984	1044	22	22.4	1.7	13
Yearlings	736	934	19	25.8	2.2	9
Average	1003	1276	26	25.3	1.6	16

It will be seen that the steers did not eat an amount of hay proportioned to either their size or their age. The large steers ate not only the largest quantity, but also the most for each 1,000 pounds of their weight; while the yearlings, although eating the least per head per day, did not eat the least per 1,000 pounds weight. The amount of hay required to produce a pound of growth is almost exactly proportional to the age. While this exact proportion is not continued through the subsequent feeding, yet, in general, the oldest steers have required the most food for each pound of growth and the youngest steers the least. Attention is especially called to the amount of hay per head per day. It is customary in Colorado to allow fifty pounds of hay per day per steer, and this is the amount thrown daily into the feed racks. Not nearly all of this is actually eaten

by the steers. The racks are cleaned out each day and about ten pounds of the hay removed. While of the other forty pounds the steers cannot eat more than thirty pounds, and the steers under consideration, though averaging just a thousand pounds live weight, ate only twenty-five pounds. The figures show that, under the ordinary method of feeding in Colorado, the steers waste from ten to fifteen pounds of hay per day per head, or from twenty to thirty tons for each hundred tons fed.

In the tests given above, the steers were fed in deep, narrow boxes, that were cleaned out every day and the amount given as eaten is the difference between the amount fed and that weighed back, so that it includes whatever waste the steers made. The refuse hay taken out of the mangers each day was fed to bulls, cows, and horses, and all eaten readily. In fact it is better horse feed than whole hay. On December 27th, the steers were separated into six groups, one of each lot of steers being put into each group.

The groups and feeds are given below:

Pen.	Name of Steer.	Age.	Weight.	Feed per Head per Day.
1	Little Roan	4.6	1212	5 lbs. cut fodder corn. 15 lbs. cut alfalfa. Cut alfalfa ad. lib.
	No. 5	1.4	693	
	Red Ear	2.6	1068	
	Average	2.9	991	
2	Strawberry	4.6	1381	5 lbs. cut fodder corn. 15 lbs. cut alfalfa. 6 lbs. cracked wheat. 20 lbs. cut beets.
	No. 3	1.4	801	
	Baldy	1.6	808	
	Average	2.5	997	
3	Spot	4.6	1357	5 lbs. cut fodder corn. 15 lbs. cut alfalfa. Cut fodder corn ad. lib.
	No. 2	1.4	684	
	Calico	2.6	928	
	Average	2.9	990	
4	Brindle	4.6	1255	5 lbs. cut fodder corn. 15 lbs. cut alfalfa. 35 lbs. corn ensilage.
	No. 4	1.4	723	
	Cody	2.6	1009	
	Average	2.9	996	
5	Whitey	4.6	1273	5 lbs. cut fodder corn. 15 lbs. cut alfalfa. 30 lbs. cut beets.
	No. 6	1.4	811	
	Sandy	1.6	871	
	Average	2.5	985	
6	Red Leg	4.6	1259	5 lbs. cut fodder corn. 15 lbs. cut alfalfa. 8 lbs. cracked wheat.
	No. 1	1.4	704	
	Cherry	2.6	1222	
	Average	2.9	1062	

Each steer was fed daily five pounds of cut fodder corn, ears and all cut into quarter-inch lengths, and also fifteen pounds of alfalfa cut into two-inch lengths. In addition to this, each steer in pen No. 1 had all the cut alfalfa it could eat, i. e., more was fed each day than the steers would eat and

the balance weighed back each day. In the same way pen No. 3 was given all the cut corn fodder they would eat. Pen No. 4 had all the corn ensilage they would eat up clean, which was found to be thirty-five pounds per head per day. Pen No. 2 had, in addition to coarse feed, six pounds of cracked wheat and twenty pounds of cut beets; these were all eaten up clean, as were also the thirty pounds of beets given to pen No. 5. Pen No. 6 was started on ten pounds of cracked wheat, but the steers were not able to handle it. It was cut down to six pounds and finally raised and and held at six pounds of cracked wheat and two pounds of corn chop per day per head. Of the hay and cut fodder corn considerably more was fed than was eaten, the balance serving to feed six head of horses and proved an economical way of using up the coarse fodder.

The steers were weighed every two weeks, the endeavor being to weigh them about ten o'clock in the forenoon, after feeding and before watering. The weighing was always done before watering, but it varied two hours in time, and this made quite a difference in the amount of feed taken into the system, especially in the pens eating beets and ensilage. Some wide differences in weights are probably due to this cause.

FEEDING RECORD, DECEMBER 27 TO JANUARY 9.

No. of Pen.	Hay Fed.	Fodder Corn Fed.	Refuse.	Hay Eaten.	Fodder Corn Eaten.	Wheat and Corn.	Ensilage.	Beets.	Total Digestible Dry matter per day per head.	Gain per day per head.
1	1132	210	265	911	166	......	....	....	12.3	1.4
2	883	281	305	653	205	205	....	700	15.9	2.9
3	630	843	831	488	654	......	....	....	11.5	2.7
4	630	210	208	474	158	......	1147	....	13.9	2.5
5	843	281	333	593	198	......	....	950	12.5	2.6
6	843	281	271	635	218	354	....	....	15.7	3.5
Total	4961	2106	1714	3754	1599	559	1147	1650	13.6	2.67

FEEDING RECORD, JANUARY 9 TO JANUARY 23.

No. of Pen.	Hay Fed.	Fodder Corn Fed.	Refuse.	Hay Eaten.	Fodder Corn Eaten.	Wheat and Corn.	Ensilage.	Beets.	Total Digestible Dry matter per day per head.	Gain per day per head.
1	1120	210	217	939	174	.....	....	....	12.7	1.0
2	804	268	358	539	180	252	....	840	15.8	1.4
3	630	880	342	493	675	......	....	....	11.8	0.6
4	630	210	220	465	155	......	1470	....	15.6	1.4
5	780	260	281	555	204	......	....	1260	13.4	2.4
6	780	260	285	552	203	374	....	....	15 0	−1.6
Total	4744	2088	1658	3743	1591	626	1470	2100	14.0	0.8

FEEDING RECORD, JANUARY 23 TO FEBRUARY 6.

No. of Pen.	Hay Fed.	Fodder Corn Fed.	Refuse.	Hay Eaten.	Fodder Corn Eaten.	Wheat and Corn.	Ensilage.	Beets.	Total Digestible Dry matter per day per head.	Gain per day per head.
1	1120	210	277	889	164	.....	....	....	12.1	2.0
2	825	275	360	555	185	252	....	840	16.0	2.5
3	630	910	366	484	690	......	....	....	11.8	2.4
4	630	210	321	389	130	......	1470	....	14.6	−0.3
5	825	275	300	600	200	......	....	1260	14 0	0.0
6	825	275	264	627	209	328	....	...	15.3	0.1
Total	4855	2175	1888	3544	1578	580	1470	2100	14.0	1.1

FEEDING RECORD, FEBRUARY 7 TO FEBRUARY 20.

No. of Pen.	Hay Fed.	Fodder Corn Fed.	Refuse.	Hay Eaten.	Fodder Corn Eaten.	Wheat and Corn.	Ensilage.	Beets.	Total Digestible Dry matter per day per head.	Gain per day per head.
1	1120	210	267	896	167	......	....	....	12.1	—1.9
2	810	270	428	468	184	252	....	840	15.1	1.5
3	630	890	304	506	710	......	....	....	12.3	—0.1
4	630	210	282	418	140	......	1470	....	14.9	3.1
5	822	274	314	586	196	......	....	1260	13.7	1.9
6	822	274	207	667	222	336	....	....	15.9	1.7
Total	4834	2128	1802	3541	1619	588	1470	2100	14.0	1.0

FEEDING RECORD, FEBRUARY 20 TO MARCH 6.

1	910	210	92	826	202	......	....	....	11.6	0.0
2	630	210	120	540	180	252	....	840	15.9	1.0
3	630	700	169	550	611	......	....	....	11.9	1.1
4	630	210	183	493	164	......	1470	....	16.1	—1.2
5	714	238	115	628	209	......	....	1260	14.3	1 2
6	714	238	62	667	223	336	....	....	15.9	2.1
Total				3704	1589	588	1470	2100	14.3	0.7

FEEDING RECORD, MARCH 6 TO MARCH 18.

1	760	180	167	628	145	198	....	....	14.3	1.2
2	552	184	96	480	160	216	....	540	15.3	—1.4
3	480	600	132	427	521	......	....	....	11.3	3.0
4	540	180	170	412	138	27	945	....	14.3	—0.4
5	612	204	137	519	160	......	....	810	12.4	—1.7
6	612	204	92	543	181	298	....	....	15.6	—0.1
Total	3556	1552	794	3009	1305	729	945	1350	13.9	0.5

FEEDING RECORD, DECEMBER 27 TO MARCH 18.

1	6162	1230	1285	5089	1018	198	....	....	12.6	0.62
2	4504	1488	1663	3235	1094	1429	....	4600	15.8	1.41
3	3630	4823	1644	2948	3861	......	....	....	11.9	1.59
4	3690	1230	1384	2651	885	27	7972	..	15.1	0.88
5	4596	1532	1480	3481	1167	......	....	6800	13.6	1.15
6	4596	1532	1181	3691	1256	2024	....	....	15.7	1.06
Total	27178	11835	8637	21095	9281	3678	7972	11400	14.1	1.12

The pens gained as follows in total weight during the 81 days of the test:

Pen No. 1 .... 150 ℔
" " 2 .... 342 ℔
" " 3 .... 357 ℔
" " 4 .... 213 ℔
" " 5 .... 273 ℔
" " 6 .... 252 ℔

Total .... 1,587 ℔

This is an average of 88 pounds per head, or one and one-tenth pounds per day per head.

SHRINKAGE FROM DIFFERENT FEEDS.

On March 13, the steers were weighed in the forenoon after feeding and before watering. They were presumably about half full. The same day they were weighed in the middle of the afternoon, after drinking, and when they probably had the heaviest weight of the day. The variations between the weights are decided. The steers weighed on the average 37 pounds more, full than half full. Pen No. 1 showed 49 pounds; pen No. 2, 36 pounds; pen No. 3, 21 pounds; pen No. 4, 12 pounds; pen No. 5, 57 pounds; pen No. 6, 46 pounds. The pen on the ensilage shows the least gain, which was to be expected; but the beet pen, showing the most, was decidedly contrary to expectation.

In individual steers, "Little Roan," on hay, gains 70 pounds; "Strawberry," on beets and grain, 85 pounds; and "Cherry," on grain, 66 pounds; while "Calico," No. 4, No. 3, and "Baldy," each make less than 15 pounds gain.

WEIGHTS AND SHRINKAGE

No. of Pen.	Feed.	Weight Dec. 27.	Weight March 13 a. m., half full.	Weight March 13 p. m., full.	Weight March 18 p. m., no water.	Weight March 19, Denver.	Probable weight if sold at farm.
1.......	Alfalfa	991	1,065	1,114	1,041	1,042	1,090
2.......	Wheat and Beets	997	1,148	1,184	1,111	1,100	1,164
3.......	Fodder Corn	990	1,115	1,136	1,119	1,033	1,126
4.......	Ensilage	996	1,115	1,135	1,067	1,018	1.120
5.... .	Beets	985	1,097	1,154	1,078	1,075	1,126
6.......	Wheat	1,062	1,183	1 229	1,148	1,175	1,206
Ave..	....	1,003	1,120	1.159	1,094	1.074	1,139

No. of Pen.	Gain from Dec. 27 to March 13, a. m.	Gain from Dec. 27 to Denver weight	Shrink from probable weight if sold on farm to Denver weight.
1....................	74	51	48
2....................	151	103	64
3....................	125	43	93
4....................	119	22	102
5....................	112	90	51
6....................	121	113	31
Average	117	70	65

The steers were shipped to Denver on March 18, at six o'clock p. m. They were not watered on the 18th, and were weighed in the afternoon before driving to the cars. So that the farm weight represents considerably less than full weight, and, on the average, it is 28 pounds less than the half-full weight of March 13, in the forenoon; showing that the steers had not eaten much food, not having water. They went to Denver that night, were unloaded into the corrals, fed and watered. They all drank, but ate scarcely anything. They were then weighed separately about

nine o'clock in the forenoon. There is an average shrink of twenty pounds from Fort Collins to Denver, and a shrink of forty-six pounds from March 13, a. m., weight. If sold in Fort Collins, it would have been "any time after 11 a. m., after feeding and watering," and would probably have given an average weight of 1,139 pounds, which is 65 pounds more than the Denver weight. The Fort Collins weight would have been subject to a four per cent. shrink, or 46 pounds, which would leave the Denver weight 21 pounds less than the Fort Collins weight with a four per cent. shrink. This is the average, but for the several pens the results are quite different. The difference between the Denver weight and Fort Collins weight with 4 per cent. shrink is, four pounds for pen No. 1; eighteen for pen No. 2; forty-eight for pen No. 3; fifty-seven for pen No. 4; six for pen No. 5; and seventeen for pen No. 6. Omitting the two pens that were fed on corn fodder and corn ensilage, the other pens together differ but eleven pounds from a four per cent. shrink. It can be said then, that, on ordinary feed, a four per cent. shrink represents very closely the difference between farm weight and Denver weight. Or, to put it in another way, cattle shrink about four per cent. from Fort Collins to Denver. When it is remembered that ten per cent. is the commonly estimated shrink from Fort Collins to Chicago, it will be seen how much advantage Denver has over the latter market

RELATIVE VALUE OF DIFFERENT FEEDS.

Corn Fodder and Corn Ensilage.---Pen No. 3 ate 2,948 pounds of hay and 3,861 pounds of corn fodder; while pen No. 4 ate 2,651 pounds of hay, 885 pounds of corn fodder, and 7,972 pounds of corn ensilage. Each pen was fed all it would eat, and if both pens consumed the same amount of nourishment, then, by subtraction (changing the surplus of alfalfa to its approximate equivalent of corn fodder), 3,373 pounds of corn fodder is equivalent to 7,972 pounds of corn ensilage. Then 2.4 pounds of ensilage is equal to one pound of corn fodder, or 100 pounds of ensilage is equal to 42 pounds of corn fodder.

As already stated, this is on the supposition that, in each case, the steers took equivalent amounts of nourishment. Or, it shows the relative amounts that will be eaten of each if the steers are fed *ad libitum*. According to the chemical composition of each, 100 pounds of ensilage should be equal to 66 pounds of corn fodder. This shows a wide difference between the two. A possible explanation is that,

in cold weather, it requires quite a share of the full feeding value of the ensilage to evaporate the extra water it contains.

The steers in pen No. 4, on ensilage, gained but little more than half as much as those in pen No. 3, on fodder corn, which shows still more unfavorably for the ensilage. Pen No. 3, weighed in Denver 43 pounds per head more than it weighed December 27, while pen No. 4 weighed only 22 pounds more, or just one-half the net gain. Some of the other pens weighed over a hundred pounds more.

If sold at Fort Collins with a four per cent. shrink, the gain in weight of pen No. 3, would have been 136 pounds per head, while that of pen No. 4, would have been 124 pounds per head. But both of these pens shrunk heavily in shipping, much more so than any other pens. If sold on the farm, not much difference would have been shown in the two pens; but what difference there was would have been in favor of fodder corn over ensilage.

Alfalfa and Corn Fodder.—The steers in pen No. 1 ate 5,089 pounds of alfalfa, 1,018 pounds fodder corn, and 198 pounds of grain, while those in pen No. 3 ate 2,948 pounds of alfalfa, 3,861 pounds of fodder corn, and no grain. Subtracting, leaves 2,141 pounds of hay plus 198 pounds of grain, which is equal to 2,843 pounds of fodder corn. This makes 100 pounds of hay equal in feeding value to about 112 pounds of corn fodder. Figured from hay to ensilage through fodder corn, gives 100 pounds of hay, equal to 269 pounds of ensilage. Alfalfa gave 150 pounds gain, and fodder corn 357, taking the weights on the farm. In Denver, the hay gives 153, while fodder corn only 129, making the two about equivalent, pound for pound, for feed. If the comparison is made on any basis of Denver weights, the ensilage made the least gain, fodder corn next, alfalfa next, and all nearly alike. If on any basis of farm weights, fodder corn is best, ensilage next, and alfalfa last, with not much difference. The steers that were fed alfalfa and fodder corn sold for the same price per pound each being ten cents per hundred pounds more than the ensilage pen.

Alfalfa and Grain.—Taking the difference between the food eaten by pens Nos. 1 and 6, leaves 1,308 pounds of alfalfa on the one side, and 238 pounds of fodder corn, plus 1,826 pounds of grain on the other. Or, the addition of a pound of grain in the ration scarcely takes off a pound from the hay eaten. This means that animals fed grain will take more total food than those fed alfalfa alone. The grain-fed steers gained nearly double as much as the hay fed.

Alfalfa and Beets.—Pen No. 5 ate 6,800 pounds of beets more than pen No. 1, and 1,839 pounds less of hay; or, one pound of hay for each 3.7 pounds of beets. This is not far from the chemical equivalent of the two. But the beets made just twice as much gain, on the basis of farm weights and 1.8 time as much on Denver weight, showing a decided advantage in the beets.

Alfalfa compared with Grain and Beets.—Pen No. 2 eats 4,600 pounds of beets, 1,231 pounds of grain, and 76 pounds of corn fodder more than pen No. 1, and only 1,854 pounds less of hay. Showing that stock take much more total food with grain and beets than with hay alone. The gain was also more than twice as much on the heavier feed, whether counted on the farm or in Denver.

Grain and Beets.—A comparison of pens Nos. 5 and 6 indicates that a pound of grain can take the place of about 2.6 pounds of beets. Theoretically, the grain-fed steers consumed the more nourishment and they made the larger gain on Denver basis and the smaller, judged by their weights, at the farm. The average of the two is about even. Commercial gains of the two are also about the same. On the face of the experiment, the beets and grain have done equally well, but the grain-fed steers received a set-back from over feeding. Hence, it is hardly safe to say what would be the comparison on even terms.

Beets compared with Grain and Beets.—The stock took much more food on grain and beets than on beets alone. They made a third more gain on the farm and a seventh more in Denver. Judged by either standard, extra grain fed with the beets did not yield a return equal to its cost.

Grain compared with Grain and Beets. A comparison of pens Nos. 2 and 6, seems to show that the total nourishment eaten is about the same. The gains are in favor of the grain and beets on the farm, and in favor of the grain alone in Denver. Financially, the two gave equal results. When it is remembered that the grain was far from its best it will be seen that the grain alone was, on the whole, superior to the grain and beets. Or in other words, the beets added to the grain ration paid less than $3 per ton. It will thus be seen that both beets alone and grain alone have given better returns than the two when fed together.

It is particularly to be noted that the pen with beets and grain ate no more total nourishment than those on grain alone, i. e., the extra beets did not enable more food to be taken. But it should also be noted that both grain and grain and beets gave more food digested than beets alone.

This indicates that thirty pounds of beets per day is a little too much for even a steer to handle.

FOOD TO PRODUCE A POUND OF GROWTH.

When the steers came to the farm they averaged 981 pounds live weight, and on March 31, under the same conditions, 1,120 pounds, a gain of 139 pounds per head, or an increase of 15 per cent. in live weight. They ate an equivalent to 45,000 pounds of hay, and 6,528 pounds of grain. Thus, each pound of growth required 18 pounds of hay and 2.6 pounds of grain, costing 5.6 cents per pound of growth. Figured in the same way, it cost 4.6 cents for each pound of growth put on the sheep fed at the College during the same winter. After deducting freight and the other expenses of marketing, the steers sold for about 3.7 cents per pound, and the sheep for 5.05 cents per pound. The sheep paid for their feed in their growth, leaving the increase of value of the carcass for profit; while each pound of growth in the steers cost more than it sold for, making a loss to be met from the increased value of the carcass.

RELATIVE CHANCES OF PROFIT IN FEEDING STEERS AND SHEEP.

A 1,000-pound steer bought at three cents a pound live weight, with a three per cent. shrink, will cost $29.10. After feeding for three months on hay and a little grain, it should weigh in Omaha, 1,090 pounds. The expenses for grain, labor, and interest, that is all the cost, except the hay, would be about $4.45, and the shipping expenses, $4.75, a total of $9.20. If sold for a cent a pound more than it cost, the returns would be $43.60, or a margin of $5.30 per steer for the hay. This would make a return of $2.65 per ton for alfalfa. Each ten cents taken off or added to the selling price of the steers will make a difference of about 55 cents per ton in the amount received for the hay.

Twenty 50-pound lambs, or 1,000 pounds of lambs will weigh in Chicago, after fattening, 1,600 pounds. They will cost for the expenses of shipment, $15, and, with grain at $12 per ton, the expense for grain, labor, interest, and dipping, will be $23, a total of $38.

If bought at three cents and sold for five cents, the cost will be $30, and the selling price $80. This leaves a margin on the twenty lambs of $12, or a return of $3 per ton for hay. Each ten cents change in the selling price makes a difference of 40 cents per ton in the returns for the hay fed.

It is evident that at these prices there is not much difference in the profits or returns from the two classes of stock. The whole problem is, therefore, narrowed to the single question, which is the more likely to happen, a difference of one cent per pound between the cost and selling price of hay fed steers if marketed in Omaha, or a difference of two cents per pound between the cost of lambs in the fall and what they will sell for on the Chicago market?

The prices of different years would give different answers to this question. During 1894-95, lambs cost $1.35 per head, with the freight paid to Omaha, which would be about $2.24 per hundred pounds live weight; and they sold for $5.50, or three and one-fourth cents per pound more than they cost. The fall of 1895 lambs cost $1.65 each, or $2.84 per hundred pounds. They sold on the average for a little less than two cents per pound more than they cost.

The steers that cost $2.50 the fall of 1894, brought $4 in Omaha four months later, while many steers that cost $3 the fall of 1895 brought at Omaha, in March 1896, but $3.50.

There is certainly a great difference of profits in these two years, but the profits in either year are not much different with sheep and cattle.

On the average, sheep have paid a little better than cattle; and, since a given change in the market affects the profits from sheep less than those from cattle, there is less danger of loss from the slight daily fluctuations of the market that are continually occurring.

Another item strongly in favor of the sheep is, the less first cost compared with feed eaten and final return. To eat 200 tons of hay requires about 100 steers at a cost of $2,900. While in sheep it requires 1,000 head at a cost of $1,600, or about one-half of the cash invested. As most of the feeding is done in this country on money borrowed from the bank, it follows that much more hay will be eaten from each $1,000 invested if the hay is fed to sheep.

MARKET PRICE AS INFLUENCED BY FEED.

When the steers were ready for market, the buyer for the Colorado Packing Company, of Denver, Mr. C. Burkhart, came to Fort Collins and priced each steer separately and then priced the bunch as a whole. The price as a whole figured within four cents per hundred of the price of each separately. The separate prices have therefore been taken as the selling price of each steer. The selling prices were as follows:

Little Roan,.	$ 3 85	Pen No. 1.
No. 5,.......	3 70	
Red Ear,....	3 85	
Average,..	$ 3 80	

Strawberry,.	$ 4 00	Pen No. 2.
No. 3,.......	3 80	
Baldy,......	3 80	
Average,..	$ 3 87	

Spot,.......	$ 4 00	Pen No. 3.
No. 2,.......	3 70	
Calico.......	3 70	
Average,..	$ 3 80	

Brindle,....	$ 3 80	Pen No. 4.
No. 4,.......	3 50	
Cody,.......	3 80	
Average;..	$ 3 70	

Whitey,.....	$ 3 90	Pen No. 5.
No. 6........	3 80	
Sandy,......	3 80	
Average,..	$ 3 83	

Red Leg,....	$ 4 00	Pen No. 6.
No. 1,.......	3 60	
Cherry,.....	4 00	
Average,..	$ 3 87	

The pens getting grain and beets and grain alone return the highest prices. Beets did next, then alfalfa and fodder corn, with ensilage last. The difference between ensilage and grain is 17 cents per 100 pounds, or a difference of more than $1 per ton for the hay, due to difference in quality of the animal as a result of the feed. It may be that this is due somewhat to the individuality of the animal and not to the feed, since Brindle was the poorest of the four-year-olds at the outset.

When compared by groups, the four-year-olds average 3.92, the yearlings 3.68, and the two-year-olds 3.82. The mature steers sell for considerably more than the younger ones, or 24 cents per 100 pounds, equivalent to about $1.50 per ton for the hay, or enough to easily change profit to loss had they been bought at the same price. But the four-year-olds cost 3 cents and the yearlings 2.65, so that the younger steers sold for a greater advance over the cost than the older. The two-year-olds cost 15 cents less than the four-year-olds and sold for 10 cents less. In general, the relation of cost and selling the price of the three bunches is within 5 cents of the average.

PROFITS OF DIFFERENT FEEDS.

The original cost of the steer added to the value of the hay at $4 per ton, eaten from the time the steer reached the farm until December 27, gives what has been figured as the cost of the steer December 27. If to this is added the cost of the food eaten during the test, it gives the cost of the steer at Denver.

The condensed statement for the six pens is as follows:

No. of Pen.	Cost Dec. 27.	Value of food eaten Dec. 27 to March 18.	Selling price in Denver.	Cost, plus food Dec. 27 to March 18.	Selling price more than cost.	Amount return for the hay eaten.
1	$ 84 70	$ 14 19	$115 24	$ 98 89	$16 35	$ 26 53
2	82 36	29 32	124 29	111 68	12 61	19 28
3	84 32	15 53	114 95	99 85	15 10	20 98
4	84 81	19 68	109 98	104 49	5 49	10 79
5	83 44	23 46	119 87	106 90	12 97	19 93
6	87 41	27 00	128 36	114 41	13 95	21 33
Total	$507 04	$129 18	$712 69	$636 22	$76 47	$118 84
Average	87 84	21 53	118 78	106 04	12 74	19 81

It will be seen from this, that the largest increase in in market value is made by the pen on beets and grain, followed by the grain, and then by the beets; the least by the ensilage. The value of the food eaten follows in the same proportion for the first three, but the alfalfa pen is the cheapest food, and the fodder corn next, leaving the ensilage about the middle. It should be remembered that these figures are based on the prices of $4 per ton for alfalfa and beets, $5 per ton for fodder corn, $3 for ensilage, and $15 for grain, being as nearly as possible the relative cost of production, and with no relation whatever to the relative feeding value. The total quantity of actual nourishment is not much different in the food of the several pens and the difference in the cost price is governed by the large differences made in prices compared with real feeding value. The feeding value of the fodder corn was probably about a quarter less than the alfalfa, and it has been figured to cost a quarter more. Ensilage has been figured at $3 per ton; whereas its feeding value would be one-half that as compared with alfalfa at $4 per ton.

The pens having the concentrated food grew the fastest, hence they made the largest increase in market value, but the market cost of their food was so great that they did not yield a correspondingly large amount of net profit. This net profit, or difference between selling price and cost plus the value of food, is most in the alfalfa and least in the ensilage. This is principally due to the fact that alfalfa at $4 per ton gives a pound of digestible material at a less price than in any of the other foods. The fodder corn comes next to the alfalfa, and is nearly as much notwithstanding the high price set on the fodder. Grain comes next, followed by beets alone and grain and beets. The three pens of concentrated food are closely even in this respect.

RETURNS FOR ALFALFA.

If from the gross receipts is subtracted all the expense except the hay, the difference may be counted as what was

received for raising and feeding out the hay. All things considered, for a man on a small farm, who does not feed more stock than he can take care of himself, this is the fairest way of calculating profits. For the outside feeder, there needs to be taken into account the net profit, minus interest, the value of his own time, all incidental expenses for horses, wagons, etc., and enough more to compensate for the risk. The home feeder has this simple problem before him: I have raised my hay. I have on hand my own teams and all equipments. In what way can I put in my time through the winter to get the largest net return from the hay I have raised?

On this basis, the alfalfa pen, of course, gives the largest return, followed by the other four pens, except the ensilage, just about even and ensilage last. But the amount of hay eaten by the pens is quite variable, and, when put into the amount received per ton, it stands as follows:

No. of Pen.	Hay Eaten.	Selling Price More than Cost, Less Hay.	Net Return for Alfalfa Per Ton.
1	5089	$26 53	$10 42
2	3336	19 28	11 55
3	2938	20 98	17 70
4	2651	10 79	8 12
5	3481	19 93	11 47
6	3691	21 33	11 56
Total	21186	118 84	11 80

When figured to return per ton for alfalfa eaten, the fodder corn shows much better than any other, with ensilage as the least. The other four are not much different, but the alfalfa pen though showing the least, yet makes the surprising showing of about $10.50 per ton, when two and a half tons were fed to three steers.

It is also shown in this view of the case, that much less hay was eaten by the other pens than by the alfalfa pen, so that to consume a given amount of hay would require more cattle, a larger outlay, and a greater risk. The extra return for the alfalfa per ton when fed with grain, beets, or both, would not more than repay the extra interest.

Looking at the matter from the point of return per ton for alfalfa fed, the alfalfa and fodder corn pens have done decidedly the best. This is the same result obtained by considering true net profit. As to which of these two pens did the better, it would be difficult to say. They are about even.

EFFECT OF AGE ON PROFIT.

In this test there were used three groups of steers, four-

year-olds, two-year-olds, and yearlings. Comparing these groups there is obtained the figures below :

	Average Weight, Dec. 27.	Average Weight, Mch. 13.	Gain in Weight.	Weight in Denver.	Shrinkage in Ship'g.	Per Cent. of Shrink.	Gain in Weight from Dec. 27 to Denver.
Four-year-olds..	1289	1419	130	1358	61	4.3	69
Two-year-olds...	984	1091	107	1042	49	4.5	58
Yearlings	736	849	113	821	28	3.3	85

The four-year-olds gained the most rapidly of the three groups, and the two-year-olds the slowest. On shipping to Denver, the four-year-olds also shrunk the most, this extra shrinking more than overcoming their extra growth ; so that the yearlings made more gain from December 27 to their weight in December than either of the other groups. These latter differences, however, are not great, amounting for the extremes to about one-fifth of a pound of growth per head per day.

When account is taken of the food eaten, as well as the growth made, the results are as in the subjoined table :

	Average Weight.	Gain in weight Dec. 27-Mch. 13.	Pounds digestible matter eaten.	Pounds digestible matter to 1 pound growth.	Value of food eaten.	Value food eaten for 1 lb. growth.
Four-year-olds ..	1354	130	1434	11.0	$8 65	$.067
Two-year-olds...	1037	107	1059	9.9	6 67	.062
Yearlings........	792	113	961	8.5	6 20	.055

The amount of food required has varied according to size, the four-year-olds eating one-half as much again as the yearlings, and the amount required for each pound of growth follows in about the same proportion. There is not so much difference in the value of the food eaten for each pound of growth, because the larger animals ate a proportionally larger amount of coarse fodder. The oldest animals ate the most value of food for each pound of growth, and the youngest the least.

If to the cost of the steer when delivered on the farm, there is added the value of the food eaten between then and December 27, when the experimental feeding began, the financial account from then until they were sold stands as follows :

	Cost Dec. 27.	Selling price in Denver.	Excess of selling price over cost Dec. 27.	Value of food eaten Dec. 27 to March 18.	Profit per steer.	Return for alfalfa per ton.
Four-year-olds ..	$39 97	$51 67	$11 70	$8 65	$3 05	$ 8 00
Two-year-olds...	27 23	37 83	10 60	6 67	3 93	10 50
Yearlings........	17 61	29 27	11 66	6 20	5 46	16 00

There is not much difference between the excess of the Denver price over the December 27 price for the three

ages of steers. But the older steers have eaten so much more food than the younger as to make nearly two dollars and a half difference per head in the profits of the feeding. This is notwithstanding the fact that the older steers sold at an average higher price per pound. When figured on to return per ton for alfalfa, the difference is ever greater, the youngest steers doubling the return from the oldest.

If instead of starting December 27, the estimate is made from the time the steers reached the farm, the results are much the same and are given below :

	First cost.	Selling price in Denver	Excess of selling price over first cost.	Value of all food eaten.	Profit per steer.	Return for alfalfa per ton.
Four-year-olds .	$37 43	$51 67	$14 24	$11 19	$3 05	$ 6 20
Two-year-olds . .	26 73	37 83	11 10	7 17	3 93	10 00
Yearlings	16 87	29 27	12 40	6 94	5 46	12 30

SUMMARY OF COMPARISON BY AGE.

These results can be summarized and show that the four-year-old steers grew the fastest ; or, a better expression would be, that they gained in live weight the fastest, since they had already grown their frame and on our feeding, they were putting on flesh and fat. At the same time these old and large steers ate a large quantity of food, the amount as compared with the smaller steers being nearly proportional to their live weights. The extra feed more than overbalanced the more rapid growth and made the amount of food eaten for each pound of growth and the cost of this food the largest of the three classes.

The shrinkage in shipping the large steers was about as much more than that for the small steers as they had gained more in live weight. So that the three classes in Denver weighed each about the same number of pounds more than when first put on feed.

In total net profit and in amount returned for alfalfa, the large steers show the poorest returns, and the smaller steers the best.

The important lesson to be learned from this test is, that well-bred steers that have been wintered on hay the first season can be profitably fed for beef and marketed when they are coming two years old. This cuts off from one to two years from the present common method of running cattle on the range. It allows more head of stock to be kept on a given range and adds at least one-half to the number that can be turned off each year.

Cattle Feeding in 1895-96.

For the feeding tests of 1895-96, 15 steers were purchased. They were grades of mixed Shorthorn and Hereford on native stock. Three of them were two-year-olds and the rest a year older, i. e., coming four the spring of 1896. They reached the farm the evening of October 22, 1895, after being driven forty-seven miles in two days. They were weighed at noon of the next day and divided into five lots of three each. Pens Nos. 1 and 6 received nothing but alfalfa hay. Pen No. 2 was fed alfalfa hay and beets, beginning with five pounds of beets per head per day and increasing a pound a day until twenty-five pounds was reached. This amount was fed constantly until January 8, 1896.

Pen No. 3 began on alfalfa hay and ten pounds of corn ensilage, increasing to twenty pounds and remaining at that amount until December 19, when barley was fed in its place. The remaining three steers were turned into a fairly good pasture and were fed in addition all the hay they would eat.

FEEDING RECORD NOVEMBER 7, TO DECEMBER 19.

No. of Pen.	Hay.	Ensilage.	Beets.	Gain in weight.
1	4552			90
2	4283		3015	88*
3	4472	2250		80
6	4230			115
Pasture				55

Feeding on Alfalfa alone.—Pens Nos. 1 and 6 received nothing but alfalfa, but Pen No. 6 gained 25 pounds more per head with a little less hay eaten. This would seem to indicate that the steers in Pen No. 6 were somewhat better

than those in Pen No. 1, although to the eye they seemed to be closely equal. The fact that, when put on grain feeding, Pen No. 1 on corn surpasses Pen No. 6, on barley and beets, notwithstanding the seeming better quality of the steers in Pen No. 6, gives added weight to the superior feeding value of corn.

The total amount of hay eaten by Pens Nos. 1 and 6, from October 23 to December 19, is 11,581 pounds. This is for six steers fifty-seven days, or 34 pounds of hay per day per head for steers that weighed on the average 1,220 pounds. If steers eat according to weight, this would be 25 pounds per day for a 1,000-pound steer. During this time there was taken from their mangers twelve pounds of hay per day per head. This refuse was fed to horses and stock cattle, so that it should not be charged against the steers. This refuse amounts to just one-fourth of the entire hay fed. The amount charged as eaten also includes the amount thrown out of the manger, trampled under foot, and wasted. The proportion of refuse holds good to the end of the winter, though the steers eating beets leave much more hay than those on grain alone. On alfalfa alone the average of the six steers from November 8 to December 19 is a gain of 112 pounds in live weight in 42 days, or 2.4 pounds per head per day. This is a greater gain than was made by either of the pens having ensilage or beets. Indeed, the poorer of the pens on hay did better than either of the ensilage or beet pens.

Alfalfa and Ensilage.—During the feeding of 1894-95 the ensilage gave the poorest result of any of the feeds used. The record is much the same for the following year. From November 7 to December 19 the three steers in Pen No. 3 ate as much hay as the average of Pens Nos. 1 and 6 that had hay alone. But, in addition to this, Pen No. 3 ate 2,250 pounds of ensilage nearly equivalent to another thousand pounds of hay, and gained less in live weight than the steers on hay alone. Thus, the addition of ensilage to the ration produced a less gain in weight from one-fifth more food. The only explanation is, that the entire feeding value of the ensilage was employed in getting rid of the extra water taken into the system with the ensilage, i. e., the ensilage was worse than thrown away.

The result of two years' feeding of ensilage shows that it is not a profitable feed for steers that are fed in the open air without shelter. These results, however, have no bearing on the question of feeding ensilage to milk cows stabled in a warm barn.

Alfalfa and Beets.—The beets were eaten greedily and were fed in liberal quantities. The steers ate 3,015 pounds of beets from November 7 to December 19 and, in addition, about as much hay as the steers that had nothing but hay. As they gained less on hay and beets than they did on hay alone, the beets were apparently more than wasted.

The pens on hay and beets and on hay and ensilage consumed nearly the same amount of food value and gained almost exactly the same amount in weight.

Fall Pasture for Steers.—During the first few days after the steers were turned into pasture they filled out nicely, but when cold weather came they almost ceased growing and from November 7 to December 19 they gained scarcely one-half as much as those fed in the pens. It was so evident that they were not doing well on pasture that, December 19, they were brought to the yards and put on hay and corn. They had, however, received such a set back that they did not recover from its effect for more than a month. Even when sold in Denver, four months later, their total gain was 79 pounds less than that of the rest of the steers.

HEAVY GRAIN FEEDING.

Heavy feeding began December 19, though the steers did not receive the largest amount of grain until about the first of March. All the pens received alfalfa hay and, in addition, Pen No. 1 received corn; Pen No. 2, wheat and beets; Pen No. 3, barley; and Pen No. 6, barley and beets.

RECORD OF FEEDING, DECEMBER 19 TO APRIL 6.

No. of Pen.	Hay.	Corn.	Wheat.	Barley.	Beets.	Gain in weight per head	Shrinkage in shipping.
1	9195	2334	....	237	756	155	8
2	7938	237	2352	....	6936	163	—27
3	8898	....	....	2574	....	76	—37
6	7524	....	237	2256	5694	141	—66

Corn versus Barley.—A comparison of Pen Nos. 1 and 3 is a test of corn and barley, each fed without beets.

The two ate nearly the same amount of hay and much the same of grain. The extra grain eaten by Pen No. 3 just about balances the extra hay and a few beets fed to Pen No. 1. Both the nutritive and commercial value of the foods eaten are equivalent. The growth is decidedly in favor of the corn. Not only did the corn make a larger growth, amounting to 79 pounds per head, but this growth was so much firmer that it shrank less in shipment. The corn-fed

steers weighed on the market 124 pounds more per head than the barley fed.

This result was unexpected when the feeding began, for barley fed to pigs had given almost as good results as corn. When fed to sheep, barley showed but a slight inferiority to corn. The barley-fed steers began to show soon after they were put onto the feed that they were not doing so well as those having corn. They ate their feed up clean, and with a fairly good appetite, but always looked worse than their neighbors fed on corn.

Corn versus Wheat and Beets.— The feeding of 1894-95 indicated that wheat and corn were about equal in feeding value, pound for pound. It was fair to presume, then, that, if beets were added to the wheat, the two together would prove superior to corn. This expectation was not realized. The winter of 1895-96 was favorable to the feeding of beets as there was but little severely cold weather. Yet, the wheat and beets produced only eight pounds more growth per head than the corn. The growth was soft and shrank considerably in shipping, so that, if judged by the market weights, the corn-fed steers gained 27 pounds each more than those having wheat and beets.

The beets took the place of part of the hay; the wheat and beet steers eating 419 pounds less of hay and 2,060 pounds more of beets. Since the hay and beets have an equal commercial value, the balance of the beets, 1,641 pounds, was wasted.

Barley versus Barley and Beets.—The preceeding comparison shows that the addition of beets to the wheat ration was without advantage. The opposite results appear, when a comparison is made, between the steers getting barley alone and those getting barley and beets. The one ate 450 pounds more hay and the other 1,646 pounds more of beets. To offset this thousand pounds of beets extra, the steers getting the beets grew nearly twice as fast as those getting barley alone, gaining 141 pounds per head, while the barley fed steers are gaining 76 pounds. Just as those having wheat and beets shrink more in shipping than the corn-fed steers, so the barley and beet steers shrink more than those on barley alone. On the market the steers having barley and beets gained 75 pounds each above their December 19 weight, while the steers eating barley alone gained only 36 pounds.

The steers on barley and beets grow nearly as fast as those on corn, but lose much of this gain in shipping, leaving the corn far ahead.

Wheat and Beets versus Barley and Beets.—The amounts of grain and beets are nearly the same, but the wheat and beets give considerable more growth than the barley and beets. Just as barley alone shrinks more than corn alone, so barley and beets shrink more than wheat and beets. In both cases the barley does not seem to make as hard flesh and fat as the corn or wheat. Judged by the weights on the market, the wheat and beets have made almost double the gain in live weight of the barley and beets.

Relative Consumption of Hay and Grain:—When the steers were eating hay alone they ate 34 pounds of hay per day per head. When grain was added to their rations, they ate less of the hay. From January 8 to April 6, while eating on the average nine pounds of grain, they ate 28 pounds of hay. A pound of grain has nearly as much feeding value as two pounds of hay; but instead of the hay eaten falling off two pounds for each pound of grain eaten, it does not decrease even so much as the weight of the grain. It is evident that when given grain the steers consume each day more actual nourishment than when on hay alone, and to this extra feed is probably due much of the extra growth made at this time.

Shrinkage in Shipping:—The steers were weighed at Fort Collins about five o'clock the afternoon of April 6 and at once shipped to Denver, reaching there the morning of April 7. They were watered and given a little time to eat hay before selling. They were consigned to Clay, Robinson & Company, and by them sold to the Colorado Packing Company, the same firm that had bought our steers a year ago. The price obtained was $3.625 per hundred pounds, being the highest price paid in the Denver market for steers during the season of 1895-96. Through the courtesy of these gentlemen, we were able to get the individual weights of the animals and judge of the amount of shrinkage that resulted from different methods of feeding. The water was shut off from the pens at noon of the day the steers were shipped, hence their farm weight represented them not at their fullest.

Upon being weighed in Denver the steers that had received corn weighed eight pounds per head *more* than at Fort Collins. The steers fed on wheat and beets

shrunk 27 pounds; on barley alone 37 pounds; and on barley and beets 66 pounds. The average of all is 28 pounds per head. This is considerably less than the steers shrunk that were fed during 1894-95, the difference being probably due to the much larger amount of grain fed the past season.

It will be noticed that the steers fed beets shrunk more than those receiving nothing but grain ; and that the steers eating barley shrunk more than those getting corn and wheat.

W. W. COOKE,

Agriculturist.

THE STATE AGRICULTURAL COLLEGE.

THE AGRICULTURAL EXPERIMENT STATION.

BULLETIN NO. 35.

ALFALFA.

Approved by the Station Council,
ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

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ALFALFA.

WILLIAM P. HEADDEN, A. M., Ph. D.

No one can feel the incompleteness of the work presented in this bulletin more keenly than the writer, or regret it more than he does. The original purpose was to make a somewhat extended investigation of the effects of alfalfa growing upon different soils, particularly upon such as had been sown to wheat for a number of successive years until the yield had fallen to an unremunerative point. The results presented are confessedly those of work preliminary to the study proper, but we deem them of sufficient interest to justify their issuance in this bulletin, as they include the composition of the plant at different stages of development for each of the three cuttings—the usual number in this locality—together with the amount and composition of the ash of the whole plant above ground at different degrees of maturity, and also of the separate parts of the plant from the roots to the seed inclusive.

In two instances the soils have been analyzed, and in one the ground water also. This is the approachment made to the original object of the bulletin.

DESCRIPTION AND HISTORY.

The history of this plant has been outlined in previous bulletins published by this and other [illegible]. The following is taken mainly from Miller's Gardener's Dictionary: The root of the cultivated Med[illegible], or Lu[illegible], is [illegible]ennial, with annual stalks one and one-half to two feet, [illegible] even almost three feet in height in good ground. The common color of the flower is a fine violet purple, but pale blue and variegated flowers are mentioned as arising accidentally from seeds. Villars affirms that the flowers are white—seldom greenish. Its native place is variously given, it be-

ing assigned to Spain and France, the Palatinate, and other portions of Europe. He adds: It may possibly have been originally a native of Europe, continuing to be disregarded until it was imported into Greece from the East after Darius had discovered it in Media, whence its name. It has been culivated "time immemorial" in the southern countries of Europe, and French Lucern seed was imported into England about 1650, but it was entirely neglected for many years, and in 1765 the fact that a farmer in Kent had fourteen acres of it was a matter worthy of mention. Lucern, he continues, has been greatly celebrated for increasing the milk of kine, but Haller, who certainly knew it well, asserts that cattle are apt to grow tired of it and that they are subject to be blown by it.

The culture of this plant by the Greeks is mentioned in their literature for about four and a half centuries, from the time of Theophrastus, 381 B. C., to that of Dioscorides, in the first century of the Christian era, and by the Roman writers through a period of about two and a half centuries from the time of Virgil, to that of Palladius, at the end of the second century, A. D. If the Persians, under Darius, introduced the Medick into Greece from Media, it would fix its date of introduction at about 490 B. C. I have not found any date given for its introduction into the Roman provinces. Its culture in Italy, however, has not been continuous down to the present time. Matthioli, writing in 1558, states that he had never seen it growing (in Italy), but adds: "It is related that it is abundantly cultivated in Spain where it is known by the Arabic name, Alfalfa." This name came with the Spaniards to this continent and has been borrowed by us directly from the Chilians, who, according to Prof. Hilgard, introduced it into California in the early fifties (1854). It was first introduced into this State in 1862, the seed being imported from California, which continued to be the source of our seed supply for several years. It has since been introduced into the contiguous states and territories.

CULTURE.

The Kansas State Board of Agriculture published, in 1894 a report devoted to Alfalfa, or Lucern, being for the most part answers given to a series of questions sent out by the Secretary of the Board, by various alfalfa growers in California, Colorado, Wyoming, Utah, Washington, Oregon, Arizona, New Mexico, Nebraska and Kansas, arranged by states and counties. The results given have, without doubt, been arrived at independently in the various regions and

probably without any knowledge of the experience and observations of European growers. The accordance between them and those recorded in this report is remarkable, and goes far to show that the general methods of culture in vogue now have been practiced in all essential features for centuries, and are probably the best admitting of general application.

The variations in culture methods are slight, though the accounts given embrace a large variety of soils and climate, and the plant is claimed to meet the requirements of an excellent forage plant under all of them, indicating its adaptability to very varied conditions. The most trying and most fatal conditions to this plant are cold, wet winters and poorly drained or water-logged soils. It has long been observed that stagnant water has a very injurious effect upon this plant, destroying its roots, an observation that Coloradoans have many opportunities of repeating. The writer has seen plants with roots entirely destroyed to within a few inches of the crown, though still producing some growth, and others killed by soils being filled up with irrigation or perhaps seepage water. In the case here referred to the soil was strongly impregnated with alkali; these salts contributed to the effect produced,but I think that the plants would have simply drowned out had there been no alkali. There are many instances of this to be observed throughout the irrigated portions of the state where depressions in the surface become partially filled with water. The principal points given for its culture are, a well prepared seed bed, "fresh and plump" seed to be covered from "very lightly" to "three inches deep," according to different observers, and varying with the climate and soil. In California and Colorado, and generally in the West, the customary practice is to drill in the seed with a protective crop. I have neither seen nor learned of drill culture being practiced except on a small scale.

In regard to the seed, some assert that two year old seed is scarcely worth the sowing, and others are quite radical in their statements as to the value of shrunken or shrivelled seed. The writer will give his reasons for refusing to accept either of these statements under the subject of "Seed." It may not be a general practice for our farmers to sell their first-class seed and use the screenings for their own sowing, but it is certainly not an uncommon practice among them, and the results are satisfactory. It is even claimed by some that no difference can be seen in the results, the screenings producing just as good a stand of healthy plants as the first-class seed. The meaning of the

persons making this claim is so evident, that there is no need of any explanation, still it may be stated that they do not claim that there will be more or less plants to the acre, but plainly that the stand will be sufficient to produce as large a crop in the one case as in the other. Some claim that the vitality of the alfalfa seed is at best small and that the shrivelled seed produce puny plants which are even less likely to survive the first summer than plants from plump seed of which, in ordinary field culture, very many perish.

Much stress is laid by some writers upon the necessity of growing the plants in a deeply prepared bed and rather abundant water supply during the first year, in order that they may establish themselves thoroughly, i. e., send their tap roots down deep into the soil. This suggestion has much force as applied to the conditions obtaining here, more, perhaps, than it would have in the East, and is by no means equally applicable to all of our lands. The root system of the alfalfa plant is greatly modified by the soil in which it grows. The so-called first bottom lands of our valleys do not favor the development of as long a root system as the higher grounds do. I have recently had occasion to study some plants which, though they were producing vigorous tops, could scarcely be said to have a tap root; for in no case, did it exceed eighteen inches in length. Had I never seen other alfalfa roots I would have considered them typical, for they were bright, without apparent deformity, and healthy. There was nothing about the plants or roots to indicate anything abnormal. The long tap roots are not always present and the old method of transplanting, as well as the continuance of gopher-eaten plants in some soils, fairly raise the question as to their necessity under all conditions. As stated above, the conditions of soil and climate prevailing here give strong justification for the practice and much force to the recommendation, but too much stress ought not to be placed upon it.

The history of fields of transplanted lucern is interesting in this connection. The practice of transplanting was at one time commended by some European agriculturists. The procedure and culture were briefly as follows: The plants were grown in seed beds in drills, were taken up in August or September, when the plants had attained a length of eighteen inches, the tap root was cut off eight, nine, or ten inches below the crown, the stalks about five inches above it, and they were then set six inches apart in rows, with two feet between the rows. This was subsequently found to be too thick. The plantation was cultivated by horse power; its duration and yield were

claimed to be greater than an equal area sown broadcast. The character of the hay produced by the two methods, especially as to its coarseness and the readiness with which it was eaten by sheep, horned cattle, and horses, did not escape observation and comment. Such a method is clearly not to be considered, but they cut the tap root off eight, nine, or ten inches below the crown of the plant, and some asserted that six or seven inches below the crown would be even better. They cut three crops of hay in England and obtained large yields. When they harvested a crop of seed they obtained only one crop of hay and considered the seed crop as injurious to the roots as four cuttings. In Italy from four to six cuttings were made; in Catalonia as many as seven, frequent irrigation being necessary to obtain so many cuttings. The hay from broadcast alfalfa is finer and softer than from drilled. The yield of hay is put at more than four tons. Such are some of the statements made of the practice and results obtained. The life of the plant grown without transplanting is variously estimated at from two to fifty years. The former is evidently too low and the latter is exceptional. Columella gives it at from ten to twelve years, which is more consonant with general observation. Miller observes that, when alfalfa is cultivated and assisted by manure, he has not observed it to decline at any age, but sown broadcast, it declines and even wears out very fast after seven or eight years. From the various statements it is evident that, under some conditions, the tap root is not necessary to the continued healthy growing of alfalfa. The susceptibility of the plant to culture and its requirement for water applied to the surface, its prompt response to the application of fertilizers, and its deportment when transplanted, suggests that we attribute more importance to the tap root than it deserves. Mr. Mills, of the Utah Experiment Station, speaking of the amount of water required by alfalfa and the part the tap root performs in supplying it, says: "Though the roots go deep and probably lift water from below, this water is not furnished rapidly enough to supply the rank growing alfalfa. The only real advantage derived from the long roots seems to be that enough water is thereby supplied to keep the plants from perishing during seasons of dry weather." The complaint that alfalfa plants are difficult to exterminate by plowing them up, is very common, and Tull is quoted as having seen alfalfa plants mangled by the plow for twenty-two successive years and still flourishing. There will be some further similarly suggestive facts found under the discussion of the roots.

It is generally recognized that alfalfa flourishes best in

an open loamy soil, but its power to adapt itself to other soils is very evident. Its doing well in heavy clay and light sandy soils, but being less productive in the latter unless well provided with plant food, attest that the plant is a heavy feeder. The range of altitude through which it will flourish is also great; while its range is less than that of timothy, it still reaches quite 8,637 feet on this side of the Rocky Mountains. I have seen a field of alfalfa in the San Luis valley, said to be fourteen years old, with an elevation of 7,900 feet, in which the stand was quite good and the plants healthy. It has also been successfully grown above Telluride, in this State.

VARIETAL DIFFERENCES.

The characteristics of alfalfa, which commend it for general culture by the farmers of the west, do not exhaust its points of interest to them. It is not constant in its specific characteristics, as almost every one has observed, some of the plants differing in color, shape, and size of both stem and leaves, and often very greatly in hue and color of flowers. The variation in color and size of the leaves is often very noticeable, and the suggestion that proper selection and careful propagation might result in establishing varieties with special merits for our climate and soils is no doubt true. The deep-green, narrow-leaved, red-stemmed plants, mostly with deep violet purple flowers, present a very different growth and mature earlier than the lighter green, larger leaved, green-stemmed and, as a rule, lighter-flowered plants. It has not been the writer's good fortune to have the opportunity of seeing many recognized varieties of alfalfa, but the few which I have seen differ less from one another, or certainly in no case more than many individual plants do growing side by side in our alfalfa fields. We have not, as we desired to do, analyzed separate plants to learn whether they have a varying composition. We have found it feasible only to take samples representing the plant as grown for hay. Among the analyses will be found, however, four samples of as many different varieties; three from French seed and one from seed from Turkestan. The results of these samples do not bear out the suggestion made above in the measure that we might expect, but the differences between the three French varieties practically disappeared in our soils and climatic conditions. The same could not be said of the variety from Turkestan. This was distinct in habit and very uniform, and, while the composition of the hay differs but slightly from the others, the agreement between them being as

close as we would expect two different samples taken from different parts of the same field to be, there is an advantage in favor of this variety because of habit, growing erect with leafy and numerous stems. As to earliness of maturity, there was but slight difference. I made no endeavor to study the relative draft made upon the soil by these varieties; in other words, the ashes were not analyzed, and only one series of samples was taken and each sample analyzed in duplicate. This is clearly too limited an investigation on which to base other than tentative conclusions, since the composition is so near to the average for alfalfa hay made from plants in the same degree of maturity. It is very probably true, that, so far as these varieties are concerned, the only advantage of any one of them over the others is an advantage due to earliness of maturity, productiveness, or the ratio of stems to leaves, and not in its chemical composition. There are, doubtlessly, other qualities entering into the alfalfa plant affecting its desirability for hay making, but which lie beyond our power to recognize, just as there is a very readily recognized difference between the different cuttings of alfalfa or between old and new hay.

The samples used in the following analyses were taken at different stages of growth for the first and second cuttings and partly so for the third cutting. We cannot give the treatment of every sample in detail without repeating to a wearisome extent. The general method was to select and cut by hand the samples to be prepared. A quantity was weighed off, cut up without loss, placed in a sack, and exposed to the wind and sun until it came to a constant weight. This process was very tedious for samples weighing from five to ten pounds. The samples were then ground, bottled, and sealed. Duplicates were made of some samples, one being dried as above, the other in the hot air bath at a temperature not exceeding 100 degrees. The analyses showed no difference due to the manner of preparation. A higher temperature, however, is not safe; this was especially true with the roots, which showed by both their color and odor that at 110 degrees decomposition of some of their constituents had set in. A temperature ranging below 70 degrees was found to answer well.

The samples were taken to represent the plant without any bloom, beginning bloom, half bloom, full bloom, with seed formed and with mature seed. The plant has been further separated into roots, the outside or bark and interior portion, stems, leaves, flowers, and seed. Two samples were taken early in May before any blossom buds appeared, for the determination of crude fiber, to ascertain

how great the relative increase of this substance is as the plant matures. Former analyses made at this Station have made it enormous.

The ashes of the principal samples have been analyzed to aid in forming some clear notion of the amount of plant food, other than nitrogen, required to produce a crop of alfalfa hay. We have no theory concerning the benefit of alfalfa growing to wheat exhausted soils, but simply seek the facts and their explanation to which, as before stated, this bulletin is simply a contribution.

PROTEIDS.

The fodder analyses of the first cutting give the following results for the amount of proteids, dates of collection being omitted except in the first instance. This sample was secured May 5th; plant 21 inches high; no blossoms; buds not visible; stem red; leaves small, dark green; air dried matter (hay) 27.53 per cent.; moisture, 72.74 per cent. Another plant with green stem, broader leaves of light green color, and equally immature as the preceding gave 28.21 per cent. hay and 74.79 per cent. water. The proteids in the above samples were respectively 19.95 per cent. and 21.79 per cent.

Proteids in first cutting alfalfa hay:—

	Per cent.
1. Plants green, (average of preceding)	20.87
2. " green, but nearing bloom	15.60
3. " beginning to bloom	14.30
4. " in half bloom	14.41
5. " in full bloom	14.08
6. " in full bloom	13.95
7. " just past full bloom	13.38
8. " in full seed	12.16
Average	14.85

Proteids in second cutting alfalfa hay:—

	Per cent.
1. Plants not yet in bloom	16.40
2. " just coming in bloom	18.47
3. " in half bloom	16.11
4. " in ½ to ¾ bloom	13.03
5. " in full bloom	12.88
6. " half ripe	12.50
7. " half ripe	11.65
Average	14.43

Proteids in third cutting alfalfa hay:—

	Per cent.
1. Hay, College Farm	12.53
2. " Rocky Ford Station	13.57
Average	13.05

The sample from the Rocky Ford Station was unusually leafy, while that from the College Farm was taken from the cock and was average hay.

The following are samples from the Farm Department, all of which were prepared by Prof. W. W. Cooke:

Proteids in first cutting alfalfa hay:—

	Per cent.
1. Hay	17.72
2. "	17.08
3. "	12.15

Numbers 1 and 2 represented individual plants cut May 28th, just before the field was mown. Number 3 is hay from the same field, cut on the 28th, but was damaged by rain.

Proteids in second cutting alfalfa hay:—

	Per cent.
1. Hay	12.15
2. "	12.29
3. Plants just showing bloom	15.26
4. " " " "	16.26

The samples of hay, Nos. 1 and 2, were cut from the same roots as Nos. 1 and 2 of the first cutting.

Proteids in third cutting alfalfa hay:—

	Per cent.
1. Hay	15.83
2. "	12.61
3. "	12.57

Condition of plants at time of cutting not given.

The average percentage of protein found in our samples for the first cutting, including all the different stages of development, is 14.85, but excluding samples cut May 5th, it is 13.98; for the second cutting, 14.43; and for the third, (this is based on too small a number of samples) 13.05. The farm samples show the same relative values for the respective cuttings, though the samples are fewer in number. For the first cutting, 14.92 per cent., for the second, 13.99 per cent., and for the third, 13.47 per cent. Perhaps analysis No. 3—first cutting—of the farm samples, ought not be included in the averages, because it was not gathered into the mow for fifteen days after it was cut, during which time it had been exposed to several rains.

As this is the only sample of alfalfa hay damaged by rains that we have analyzed, we will make mention of it in this place. The average of the analyses made of samples taken from the same field and cut the same day, but dried in an air bath, shows the composition of the prime water-free hay to be:—

	Per Cent.
Ash	12.18
Crude Fiber	26.46
Crude Fat	3.94
Crude Protein	18.71
Nitrogen free extract	38.71
	100.00

The sample of damaged hay gives :—

	Per Cent.
Ash	12.71
Crude Fiber	38.83
Crude Fat	3.81
Crude Protein	11.01
Nitrogen free extract	33.64
	100.00

The total rainfall between May 28th and June 12th, the respective dates of cutting and of putting into the mow, was 1.76 inches. The weather during this time was cloudy and the temperature ranged from 72 to 81 degrees. Any calculations based upon the above, without further data, would evidently be liable to lead to erroneous conclusions, but it suffices to show that the popular estimate of the value of such hay is not far from correct, i. e., about one-half that of good hay. The damage is not simply the amounts of proteids and nitrogen free extract (carbohydrates) lost, but also the loss of those general qualities recognized as essential to good hay. The mechanical loss in such cases is very large. We undertook to determine by direct experiment the total loss by the solvent action of water, fermentation, and handling, but it became evident that the results would indicate nothing of general value because there was no limit at which we would have to stop and no criterion by which we could judge when our experiment had become comparable with the average article (if there be such) of damaged hay. This sample gives us a somewhat definite measure of the sensitiveness of this hay to rain and exposure. The rain fell in three portions: the first fall amounted to .31 inch; the second 1.49 inches; and the third .27 inch, with intervals of two days or more. The weather was cloudy and warm. The mechanical loss of leaves and stems would tend to change the composition of the hay in the direction indicated by the analyses, but for good reasons, we do not consider this to enter largely into this particular case; but attribute the changes in the composition of the hay to the action of the moisture and heat.

Judging by the amounts of proteids in the three different cuttings, the first and second cuttings stand very close to each other in value with the difference in favor of the first cutting. In the farm samples, leaving out the damaged sample, the first cutting is materially the best of the three. I would here remind the feeder, who prefers the second or even the third crop for certain feeding, that the amount of proteids present is not the only measure of good hay. Not only is the quantity of proteids greater in the first cutting, but the yield is also greater and the hay cut just at the beginning of bloom is richer in this constituent than when cut later. From beginning bloom to half bloom the amount of proteids seems to be nearly stationary and the crop is also probably at its maximum. There are no figures accessible to me on this point, but it is in keeping with my observations. If the plant continues to store up organic matter after this period is past, I am inclined to think that the loss by the dropping of leaves, due to the maturing of the plant and the action of the fungus common on our alfalfa, more than compensates for the gain. While I am inclined to think that the farm samples are exceptional in their quality, they confirm the results obtained on the laboratory samples and make the first cutting very decidedly richer than the second. The development of the plants is not given, but as the date of cutting was May 28th and it was intended to cut the field four times, it was probably just before bloom, in which case the apparent excessive richness in proteids is largely and probably wholly accounted for. If the very early cutting be rejected from my series, and I think this should be done for no one would cut the crop so immature, it changes the results in favor of the second cutting.

CRUDE FIBER.

It has been stated by others that this portion of the plant increases materially with age. Our results indicate the same, but not to the extent claimed in a former bulletin issued by my predecessor, wherein he showed it to increase from 12.88 per cent. in hay, cut when the plant was beginning to bud, to 20.23 per cent. in hay made from alfalfa with fully ripened seed. (Bulletin No. 8, of this Station, page 11, analyses Nos. 1 and 4.) The method of determination is given as that adopted by the Association of Official Agricultural Chemists, convention of 1888. Whatever influence of the greater or less succulency of the plant may have upon the amount of crude fiber in the dry matter, it cannot in this case be appealed to to account for the low percentage of fiber, for the percentage of dry matter in the

plant is given in some cases even higher than any which we have found. In Bulletin No 8, it is given as ranging from 22 to 50 per cent. of the green weight. In two samples cut on May 5th, we found the dry matter to be 25.2 per cent. and 27.53 per cent., and the crude fiber to be 22.56 per cent. and 29.79 per cent. respectively. These samples were taken from two separate and very unlike plants, grown without cultivation or irrigation. The average of these two, 26.18 per cent., is near the truth for alfalfa hay cut before flowering. Differences in cultivation, and varieties may make a difference of a few per cent.

Laboratory Samples.

Crude fiber in first cutting alfalfa hay:—

		Per cent.
1.	Plants quite young (average)	26.18
2.	" in bud	35.17
3.	" in bud	37.39
4.	" in half bloom	36.54
5.	" in full bloom	40.18
6.	" in full bloom	32.48
7.	" just past full bloom	36.19
8.	" in full seed	46.12
	Average	36.28

Samples numbered 5 and 6 were collected in different localities. No. 5 from heavy first bottom land; the growth was very rank, many of the stems were upwards of five feet in height; and the average diameter of one hundred stems, taken large and small as they grew, was nearly one-fifth of an inch—.19. The lower portion of such stems was woody and devoid of leaves. The stems in numbers 3 and 4 (100 from each sample), were also measured and were only a trifle smaller, having an average diameter of .17 of an inch. The sample on which analysis numbered 6 was made grew on a sandy loam, without irrigation. The plants had an average height of three and a quarter feet; and were very leafy, probably more so than the average.

The following are also laboratory samples of first cutting hay, but made from supposedly distinct varieties, grown on a rich loam, in drills, with irrigation:

Crude fiber in first cutting alfalfa hay:—

		Per cent.
9.	Plants in full bloom	36.39
10.	" in full bloom	32.74
11.	" in full bloom	35.51
12.	" in full bloom	31.96
	Average	34.15

The average of which is 34.15 per cent., while that of Nos. 5 and 6 is 36.33 per cent., which is probably the range of the average percentage of crude fiber of first cutting alfalfa hay cut when the plant is in full bloom; while the average percentage of the samples taken before blooming, including those taken as early as May 5th, is 32.91 per cent., the lowest being 22.56 per cent. and the highest 37.39 per cent., the difference being due to development of the plant and to the differences of conditions under which they were grown, particularly of soil and irrigation.

Crude fiber in second cutting alfalfa hay:—

		Per cent.
1.	Plants not in bloom	28.66
2.	" coming in bloom	32.46
3.	" in half bloom	37.39
4.	" in half bloom	37.24
5.	" in full bloom	38.06
*6.	" past full bloom	31.10
	Average	34.15

Crude fiber in third cutting alfalfa hay:—

		Per cent.
1.	Hay, College farm	39.35
2.	" Rocky Ford station	34.67
	Average	37.01

Farm Samples.

Crude fiber in first cutting alfalfa hay :—

		Per Cent.
1.	Hay, cut May 28	24.54
2.	" " "	24.68
**3.	" " "	35.09
	Average	28.10

Crude fiber in second cutting alfalfa hay:—

		Per cent.
1.	Taken 35 days after first cutting	26.16
2.	Taken 35 days after first cutting	29.07
3.	Taken about 48 days after 1st cutting	34.59
4.	Taken about 48 (?) days " "	38.08
	Average	34.37

*This sample was obtained from the farm of Charles Evans, northeast of Fort Collins. The land is high and under irrigation. The alfalfa was average in growth. Its age is not known to us.

**This sample was damaged by rain.

Crude fiber in third cutting alfalfa hay:—

		Per cent.
1.	Hay	28.89
2.	"	37.39
3.	"	34.91
	Average	33.70

As already remarked, the results, especially of the laboratory samples for the first and second cuttings, show an increase in the crude fiber as the plant matures, but there is a considerable variation in the samples, with a few apparent contradictions, which is to be explained by differences under which the samples were grown and taken. The determinations were made in duplicate, and sometimes in triplicate, or until we were satisfied that the difference in the results was in the sample and not in the analyst's work. From the beginning of bloom to half bloom, the increase is not very rapid and the averages obtained for the hays of different cuttings are nearly equal, at least not so far apart as public judgment assumes; for the first, 35.21 per cent.; for the second, 34.15 per cent. (laboratory sample), 34.47 per cent. (farm sample); and for the third cutting, 37.01 per cent. ; 33.70 per cent., three samples of hay from the farm department.

FAT OR ETHER EXTRACT.

We find in our laboratory samples a considerable variation in the amount of fat. If the differences be expressed in terms of the total fat found, they are large; but if in per cent. of the sample, they are constant. In twenty samples of alfalfa hay, but one yielded as much as 2 per cent. or more of fat soluble in ether, and only one below 1.1 per cent., with the average equal to 1.539 per cent. In the case of the farm samples, though our results on the duplicates were satisfactory, there is no concordance when the series of samples is taken as a whole, one sample falling as low as .86 per cent., and another in the same sub-series giving 2.76 per cent.; and still another 4.20 per cent. We have been unable to discover any reason for such variations in the farm series itself and quite as unable to find out why the two series should be so different. If we neglect the samples of first cutting hay in the farm series and take the samples representing the second and third cuttings, the average for the fat is, 1.641 per cent.; while the average fat content of the twenty laboratory samples is, 1.539 per cent., with most of them quite close to the average.

The fat as determined in the sample in full seed is, doubtlessly, too low (1.03 per cent.) for the reason that any

seed which was in the hay was not crushed in the grinding of the sample and would yield so good as none of its fat in the sixteen hours' treatment with ether. We subsequently established this fact by direct experiment with whole unhulled seed. With this one exception, if it is an exception, there is no clearly indicated difference in the amount of crude fat present at the different stages of development examined in this study.

NITROGEN FREE EXTRACT.

The substances embraced under this name, having heretofore been determined by the difference between the sum of the proteids, crude fiber, fat, ash and moisture, and one hundred, will vary inversely as and quite nearly with the substance present in the largest quantity, which is the crude fiber. By this we mean that, if the crude fiber is high, the nitrogen free extract, which includes sugar starch, etc., called carbohydrates, will, as a rule, be lower than in another sample having less crude fiber. If the direct determinations have been made with care, the nitrogen free extract determination will be quite accurate enough for all purposes.

Laboratory Samples.

Nitrogen free extract in first cutting alfalfa hay:—

		Per cent.
1.	Plants not in bloom	29.79
2.	" not quite in bloom	32.91
3.	" half bloom	32.50
4.	" full bloom	27.85
5.	" full bloom	37.64
6.	" full bloom	30.59
7.	" full bloom	33.24
8.	" full bloom	33.11
9.	" full bloom	31.41
10.	" just past full bloom	30.41
11.	" full seed	29.22
	Average	31.69

Nitrogen free extract in second cutting alfalfa hay:—

		Per cent.
1.	Plants not in bloom	36.49
2.	" coming in bloom	31.58
3.	" half bloom	33.29
4.	" half bloom	28.90
5.	" full bloom	32.02
6.	" past full bloom	39.45
7.	" past full bloom	38.13
	Average	34.27

Nitrogen free extract in third cutting alfalfa hay :—

		Per cent.
1.	Hay, College Farm	31.35
2.	" Rocky Ford Station	34.09
	Average	32.72

It ought to be mentioned, perhaps, that these samples are from different places, some grown with and others without irrigation on different soils. With the exception of analysis No. 4, first cutting, the results indicate that the nitrogen free extract is greatest at or about full bloom.

Farm Samples.

Nitrogen free extract in first cutting alfalfa hay :—

		Per cent.
1.	Hay, cut May 28	35.67
2.	" " " "	36.42
3.	" damaged by rain	30.97
	Average	34.35

Nitrogen free extract in second cutting alfalfa hay :—

		Per cent.
1.	Cut 35 days after 1st cutting	32.77
2.	" " " " "	31.11
3.	" about 48 (?) days after 1st cutting	37.84
4.	" " " " " " "	34.43
	Average	34.04

Nitrogen free extract in third cutting alfalfa hay :—

		Per cent.
1.	Hay	36.78
2.	"	34.81
3.	"	35.84
	Average	34.74

The moisture in our samples of air dried hay ranges from 4 per cent. to nearly 9 per cent., with an average of 6.21 per cent., for the first; 5.94 per cent., for the second and 5.93 per cent. for the third cutting; while the average for all three is 6.03 per cent. Such hay takes on moisture readily. While preparing our first cutting samples, we had a spell of damp weather lasting from July 3d to 6th. during which some samples gained as much as 5.70 per cent. The smaller samples gained more proportionately than the larger ones because there was relatively more surface exposed.

The moisture in the farm samples is higher than in the laboratory samples. This is noticeably the case with the

second cutting; the results are, for the first cutting, 7.59 per cent.; for the second, 8.05 per cent.; and for the third, 5.63 per cent. The average of the three is 7.09 per cent., from which we may judge that the moisture in alfalfa hay, under average Colorado conditions, is not far from 6.52 per cent. and not above 7.09 per cent.

ASH OR MINERAL CONSTITUENTS.

This component in alfalfa hay has some importance in general feeding, but very much more for the purpose of this bulletin as a measure of the draft made upon the plant food in the soil, both as to kind and quantity. I have not considered the physiological function of the constituents of the ash to be of such importance as to require any attempt to determine for instance the amount of phosphoric acid existing as such in the hay as fed, but have simply determined the amount of this acid in the ash, as prepared; though it is almost certain that some of the phosphorus determined in the ash as phosphoric acid does not exist as such in the plant. The same can be said of sulphur. The total amount of this in the plant has been determined in several instances; not, however, with the purpose of determining the portion present as sulphuric acid and that present in other forms, but simply to get the total sulphur in the form of sulphuric acid.

The amount of ash in alfalfa hay varies with different plants, different soils, etc. We do not speak here of the variation in the amounts of the different constituents, but simply of the total ash present.

ASH IN ALFALFA HAY.

Laboratory Samples.

First cutting:—

		Per cent.
1.	Plants quite young, (cut May 5)	10.64
2.	" quite young, (cut May 5)	12.16
3.	" not in bloom	10.21
4.	" not in bloom	9.14
5.	" in half bloom	9.30
6.	" in full bloom	10.46
7.	" in full bloom	9.24
8.	" in full bloom	9.94
9.	" in full bloom	10.19
10.	" in full bloom	10.99
11.	" in full bloom	11.34
12.	" just past full bloom	9.93
13.	" in full seed	6.77
	Average	10.03

Second cutting :—

		Per cent.
1.	Plants not in bloom	10.51
2.	" coming into bloom	11.95
3.	" in half bloom	9.48
4.	" in half bloom	9.91
5.	" in full bloom	10.97
6.	" half ripe	8.87
7.	" half ripe	9.98
	Average	10.24

Third cutting :—

		Per cent.
1.	Hay, College Farm	9.38
2.	" Rocky Ford Station	10.28
	Average	9.83

The percentages given above are practically for fine or pure ash, numbers 1 and 2, for the first cutting, being the only ones which ought to be designated as crude ash. The average percentage of ash for the first cutting, after rejecting the first and last two analyses, for no one would cut either of these samples for hay unless compelled to, is 9.08 per cent.; for the second cutting, 10.24 per cent.; and for the third cutting, 9.83 per cent.

Farm Samples.

First cutting :—

		Per cent.
1.	Hay	10.97
2.	"	11.68
3.	" damaged by rain	10.94
	Average	11.19

Second cutting :—

		Per cent.
1.	Hay, cut 35 days after first cutting	9.72
2.	" cut 35 days after first cutting	10.31
3.	" cut about 48 days after first cutting	11.26
4.	" cut about 48 days after first cutting	10.63
	Average	10.48

Third cutting :—

		Per cent.
1.	Hay	10.29
2.	"	9.94
3.	"	9.99
	Average	10.07

These percentages represent the pure ash, excepting the small amount of sand contained in them. The averages for the respective cuttings are as follows: first cutting, 11.19 per cent.; second cutting, 10.48 per cent.; third cutting, 10.07 per cent. The average for the two series is, for the first cutting, 10.35 per cent.; for the second cutting, 10.28 per cent.; and for the third cutting, 9.95 per cent. From which it appears that there is but little difference in the amount of mineral constituents removed by a ton of first, second and third cutting hay; the lowest figures requiring 199 pounds and the highest 205.6 pounds. While the percentage of ash found is not correct, due to loss of some of the constituents of the ash, chlorine and sulphur, these numbers serve to show very clearly that a five ton crop, which is some times obtained, forms a heavy drain upon the mineral elements of plant food, amounting to not less than 871 pounds per acre, after deducting the carbonic acid in the ash, or 1,025 pounds if we do not make this deduction.

WATER IN ALFALFA.

The moisture given up by green alfalfa in becoming well cured air dry hay, is as follows:

	Per cent.
1. Plants cut very young	74.79
2. " " " "	72.74
3. " in bloom	70.90
4. " in bloom	72.65
5. " half bloom	73.06
6. " full bloom	73.61
7. " full bloom	74.06
8. " full bloom	73.22
9. " full bloom	73.67
10. " full bloom	71.45
11. " full bloom	74.39
Average	73.14

Second cutting:—

	Per cent.
1. Plants not in bloom	71.52
2. " coming in bloom	74.35
3. " in half bloom	68.65
4. " in half bloom	70.40
5. " in full bloom	74.50
*6. " half ripe	62.91
Average	71.08

* Not included in average.

As our analyses of the third cutting were made on hays, as prepared to put in the mow, we have no figures showing the amount of moisture lost in curing.

The average of the eleven samples of first cutting is 73.14 per cent., which means that every 100 lbs. of alfalfa as it stands in the field will give 26.86 pounds of well cured hay for the first cutting. An examination of the preceding table shows that there is not so great a difference in the amount of moisture in the alfalfa at the different stages of its growth at which it is cut for hay, or even for soiling, as might be supposed.

The average for the second cutting is some lower than for the first, but no very immature samples are included. The number of samples is also smaller, i. e., five samples with an average of 71.08 per cent. according to which each 100 pounds green crop gives 28.92 pounds of hay at second cutting. These results are much more uniform, and indicate less loss on account of moisture than those given by others. The average moisture in alfalfa hay, first cutting, is 6.03 per cent., the average of 13 samples, lowest, 3.77; highest, 8.87; for the second cutting, 5.94 per cent., the average of nine samples, lowest, 4.31; highest, 7.25. The average water content of green alfalfa, at time of first cutting, is 74.76 per cent., and at time of second cutting, 72.80 per cent.

Dr. Allen kindly furnished me with the results recorded by Dietrich and Koenig as 76 per cent. at beginning bloom; also 76 per cent. at full bloom. These are averages, the former of results ranging from 72.2 to 82 per cent.; the latter of results ranging from 70.0 to 83.1 per cent. The New Jersey Report for 1888, gives water for first cutting as 79.46 per cent.; for second, 64.37 per cent., alfalfa in drills; 80.61 per cent. for first cutting, 61.69 per cent. for second cutting, when sowed broadcast. The uniformity in our results is probably attributable to our climatic conditions and mode of culture, rather than to differences in the soils of New Jersey and Colorado. The New Jersey averages show the first cutting to contain more water, or to be more succulent than the second; while the results recorded in the Texas Bulletin No. 20, 1892, show the reverse, i. e., for the first cutting, 69.40 per cent., average of four analyses with 62.44 per cent., as the lowest, and 75.65 per cent., as the highest, and for the second cutting, 76.54 per cent. with 71.77 per cent. for the lowest and 81.59 per cent. for the highest.

AMIDE NITROGEN.

The proteids as given represent the whole of the nitro-

gen. There should, however, be a slight reduction made because of the fact that some of the nitrogen is present in a form of much less value than the proteids. The second column in the accompaning table gives the percentage of the total albuminoids corresponding to the amide nitrogen found. The following is the amount of amide nitrogen found in the respective samples :

First cutting :—

	Per cent. Amide Nitrogen.	Per cent.
1. Plants not in bloom	0.284	11.30
2. " not in bloom	0.187	7.48
3. " in half bloom	0.372	16.16
4. " in full bloom	0.176	7.80
5. " in full bloom	0.230	10.22
6. " in full bloom	0.239	12.26
Average		10.85

Second cutting :—

	Per cent. Amide Nitrogen.	Per cent.
1. Plants coming in bloom	0.517	17.82
2. " in half bloom	0.350	13.59
3. " in half bloom	0.614	29.47
4. " in full bloom	0.393	18.84
Average		19.93

Third cutting :—

Hay, College Farm	0.100	5.03

The proportion of proteids in the nitrogenous substances of alfalfa is represented, according to these results, by 89.13 per cent., for the first cutting ; 79.93 per cent. for the second cutting ; and 94.97 per cent. for the third. The percentage here given for the third cutting being based upon a single sample of hay, and at variance with the other results, is at best doubtful ; it is, however, the result obtained. I have found but one other series of analyses of alfalfa, in which the amide nitrogen is given, i. e., by Mr. H. H. Harrington, in Texas Bulletin No. 20, 1892. The dates on which the samples were taken are given instead of the development of the plant ; but, as the period of collecting covers forty days, I infer that the samples represent successive stages of development corresponding approximately to those given in this bulletin. The third column gives the percentage of total proteids corresponding to amide nitrogen found :

	Per cent Total Nitrogen.	Per cent. Amide Nitrogen.	Per cent.
Apr. 20	2.90	1.08	37.19
" 29	3.19	1.22	38.24
May 11	3.07	1.32	43.01
" 30	2.45	.46	18.77
" 30 (2d cut)	3.77	1.10	29.29
Average			34.31
Alfalfa not irrigated :—			
Apr. 3	4.12	0.13	3.14
" 21	4.11	1.15	28.00
May 11	2.78	0.80	28.85
Average			19.99

According to this series of analyses the proteids make up for the average, 65.69 per cent. of all the nitrogenous compounds in the first cutting alfalfa hay grown under irrigation ; and 70.71 per cent. of those of the second cutting grown under like conditions. But of these compounds, in the first cutting grown without irrigation, the proteids form 86.69 per cent., if we take the average of the three determinations given, or 71.58 per cent. if we leave out the sample taken April 3, which brings it in better accord with the other results.

These two series of determinations show clearly that the total amount of nitrogen in two different samples of hay, grown under different climatic conditions and expressed as proteids, cannot safely be taken as a measure of their relative value for feeding. As an example in point we will compare the Texas sample, collected May 11, with our sample of first cutting hay,made when the plant was in half bloom. According to Mr. Harrington's analysis, the Texas sample shows, nitrogen equal to 19.18 per cent. proteids or albuminoids, and our own air dried sample 14.41 per cent. We should, accordingly, give preference to the Texas hay, but, when we deduct the amides, we find the Texas sample has 10.97 per cent.; while the Colorado sample has 12.08 per cent. of the more valuable albuminoids left. So far as these are a measure of the feeding value of hay, the Colorado sample is really the better. If the plant were to be turned under as a manure, the more nitrogen the better, other things being equal. The difference in the amount of amides present in the two series is very great, but the methods used by the analysts were the same, the figures corresponding closely to the difference in the samples.

Our series of samples shows that the second cutting is

richer in amides than the first cutting, which is still the case if we reject analysis No. 3, which seems abnormally high and for which we have no explanation to offer; also, that the amides attain their maximum in the whole plant at about the time of half bloom. It may here be remarked that the flowers, an analysis of which will be given later, are also quite rich in these amide compounds, and their abundance at the time of half bloom may determine the time of the maximum amount of amides. There is not the same fluctuation in our results as is shown in those of Mr. Harrington; they agree in showing a disappearance of these compounds as the plant begins to go out of bloom.

NITROGEN AS NITRIC ACID.

The well-known effect of alfalfa hay, particularly new hay, upon horses and the detection of large quantities of potassic nitrate in cornstalks grown under peculiarly favorable conditions, suggested the possibility of the occurrence of nitric nitrogen in this rapidly growing plant. The albuminoidal nitrogen was determined according to Stutzer's method, the filtrate rendered alkaline and subjected to distillation until ammonia ceased to be given off. The residue was acidified with sulphuric acid,run in from a graduate, and the nitric acid reduced by nascent hydrogen with the usual precautions, and after complete reduction, rendered alkaline again and distilled. The average of the results thus obtained gave us exactly the average of the blanks made with our reagents by Kjeldahl's method. The number of tests made was eighteen, and the nitric nitrogen was absent or present in exceedingly minute quantities. The roots were not tested for nitric nitrogen, but as the amids are present in them in rather large quantities, it is doubtful whether they contain more nitric nitrogen than the rest of the plant.

THE PLANT.

The preceding paragraphs have dealt with the whole plant as represented in hay, including leaves, flowers, and stems. The laboratory samples were prepared in such a manner as to preserve all the plant, and they consequently preserve the natural ratio of the different parts of the plant, which is not true of field-cured hay. In the succeeding paragraphs is given the composition of the separate parts of the plant, i. e., stems, leaves, flowers, seeds, and roots.

STEMS AND LEAVES.

Reference has already been made to the size which these attain, the diameter of 300 stems giving an average of nearly .17 of an inch, and they attain a hight of five and

one-half feet under favorable conditions. It is a somewhat hackneyed observation that horses eat them (stems) more readily than they do the leaves, if not all too coarse; while cattle prefer the leaves. The percentage of stems and leaves, including flowers, varies with different plants from 40 to 60 per cent. A very leafy, small-stemmed plant may have more than 60 per cent. leaves and, consequently, less than 40 per cent. stems, but the stems of an average plant will amount to between 40 and 60 per cent. These numbers are of importance when it concerns hay making, as common experience teaches that the leaves are readily lost if the hay is not handled carefully and advantageously. In as much as many of the smaller stems may go with the leaves, the loss in making hay can, and in some cases, does amount to from 50 to 60 and even more per cent. We undertook to determine, by weight, this loss in making hay, but desisted after a very brief trial for reasons similar to those given under the subject of damage done to hay by rain. We have been led by our experience and observation, to the conclusion that the minimum loss from the falling off of leaves and stems in successful hay making amounts to from 15 to 20 per cent., and in cases where the conditions have been unfavorable, as much as 60 or even 66 per cent. of the dry crop, or, for each 1,700 pounds of hay taken off the field, at least 300 pounds of leaves and small stems are left, and, in very bad cases, as much as 1,200 pounds may be left for each 800 pounds taken. Of course, the latter is extreme, but it does occasionally happen even in this land of perpetual sunshine. The chemical loss has been referred to under proteids, farm sample, first cutting, analysis No. 3.

The stems loose 59.79 per cent. of their weight in curing, and yield 40.21 per cent. of air dry substance with the following composition:

	Water.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.	Amide Nitrogen.
Air cried	5.41	4.91	.94	6.34	54.40	28.00	1.015	0.07
Air dried	5.71	4.99	.85	6.35	54.32	27.79	1.015	[0.07]
Water free	....	5.19	.953	6.479	57.51	29.87	1.035	....
Water free	....	5.30	.900	6 469	57.61	29.72	1.035	....
Digestible	....	....	.456	4.63	25.00	20.21	.....	....
Ratio, 1 : 10.								

This shows the stems to be very high in crude fiber and low in nitrogen free extract, while the proteids are almost equal to the average amount in timothy hay and the fat is less than one-half as much. Assuming the coefficient of digestibility for the stems to be equal to the average coeffi-

cient of digestibility for alfalfa as given by the New York and Colorado Stations, we have in the stem the following proportions: Digestible fat, .456 per cent; proteids, 4.63 per cent; crude fiber, 25.00; nitrogen free extract, 20.21 per cent., with a nutritive ratio of 1.10, requiring the addition of about 1.31 per cent. of digestible proteids to make the nutritive ratio 1 : 7.8, Wolff's standard ratio for horses at moderate work. The stems used in the above analyses were very coarse for alfalfa stems, and the proportion of fine stems was small. I interpret the high percentage of crude fiber as indicating this, which I otherwise know to be a fact. The stems as selected by horses from the hay probably approach considerably neared to the ratio of an agreeable, sufficient, and advantageous ration than that deduced from the above analyses. The amide nitrogen is very low.

LEAVES.

The samples of leaves were carefully picked free from all stems. They were not free from the fungus, which causes the dark brown spots and which is described in the Third Annual Report of the Delaware Station, 1890, page 79, under the name of *Pseudopeziza Medicaginis;* also in New Jersey Report for 1889, pages 152-160, as *Phacidium Medicaginis.* This fungus was so prevalent at the time of gathering the leaves, that the avoidance of every affected leaf was practically impossible. The affected leaves were not sufficient in number to have any perceptible effect upon the results. Analyses of affected leaves may be found in the New Jersey Report referred to above. Fresh leaves yield 68.72 per cent. water and 31.28 per cent. air dried matter. The water is low, for one cannot pick them without their wilting somewhat.

COMPOSITION OF LEAVES.

CONDITION.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.	Amide Nitrogen.
1. Early bloom	4.63	14.29	2.94	24.33	13.12	40.70	3.892	....
2. Early bloom	4.93	14.48	2.96	23.33	13.15	41.16	3.732	....
Water free	....	15.03	3.08	25.50	13.76	42.63	4.088	....
Water free	....	15.54	3.11	24.50	13.83	43.42	3.920	....
3. Early bloom without irrigat'n	8.40	13.60	4.10	22.18	10.67	41.05	3.549	....
4. Early bloom, without irrigat'n	8.53	13.35	3.43	22.60	10.66	41.45	3.639	....
Water free	....	14.84	4.77	24.24	11.37	44.78	3.878	....
Water free	....	14.61	4.75	24.69	11.65	45.30	3.950	....
5. Half bloom	8.62	11.39	4.28	22.30	12.48	40.90	3.568	....
6. Half bloom	8.38	11.39	4.28	23.31	12.48	40.60	3.733	....
Water free	....	12.48	4.69	24.30	13.65	44.88	3.892	....
Water free	....	12.48	4.69	25.29	13.65	44.09	4.046	....
7. Past full bloom	4.49	14.50	2.88	20.20	16.16	41.77	3.232	.506
8. Past full bloom	4.52	14.51	3.05	20.20	16.00	41.72	3.232	....
Water free	....	15.19	3.02	20.73	16.92	44.14	3.319	....
Water free	....	15.19	3.19	20.73	16.72	44.17	3.319	....
Digestible	....	....	1.47	14.75	7.43	28.40	....	....
Nutritive Ratio—1 : 2.7.								

The high percentages of ash and proteids are the salient features of the composition of the leaves. Using the same coefficients of digestion as before, we obtain a nutritive ratio of 1:2.7, a very close ratio and one on which probably no animal will do so well as on a wider one. The large percentage of ash may have some effect upon the taste of the leaves; such is readily conceivable. The ash constituents will be discussed later in connection with the fertilizing value of the leaves. As the mechanical loss suffered in hay making consists very largely of leaves, they play an important part in the improvement of the soil observed in such as has been to alfalfa for a few years and in the quality of the hay.

FLOWERS.

The flowers do not constitute at any period in the growth of the plant a large percentage of the whole, but as their appearance is the sign of the approaching retrogression of some of the food constituents, or indicates the turning point in the life of the plant, we have submitted them to analysis to aid in tracing the course of development and also of the mineral constituents. The water in them is quite as much as in the average plant, i. e., 72.69 per cent.; and the air dried matter 27.31 per cent. This sample was gathered with great care and then sorted, so that there should be nothing but the racemes of flowers, without seed pods, except very young ones. The racemes taken presented the largest number of full blown flowers and probably contained the maximum of food stored up preparatory to the formation of seed.

COMPOSITION OF THE FLOWERS.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen	Amide Nitrogen.
Air Dried	4.46	9.41	2.11	21.33	19.92	42.77	3.413	.692
Air Dried	4.78	9.68	....	21.48	20.08	......	3.437	......
Water Free	....	9.85	2.21	22.35	20.85	44.74	......	......

The ash scarcely differs from the amount present in the whole plant, but the proteids and nitrogen free extract are very much higher; the former seemed probable without the analytical results and it is almost evident that they should be rich in carbohydrates. The function to be fulfilled by the accumulation of these two important components does not come within the scope of this bulletin, even if we were competent to discuss it, but it is suggestive

that these two components are also present, the proteids in even larger proportion, in the seed. The ether extract, however, does not foreshadow the large amount of oil in the seed. The proteids are most abundant in the hay, when cut at about half bloom, as the flowers themselves do not form a sufficient percentage of the hay to account for the total increase; it is probable that there is really more proteids elaborated just before or at this period of growth than at any other. In making this statement we bear in mind the total weight of the plant as well as the percentage composition. Some of our analyses indicate that the dry matter contains a higher percentage of proteids if the hay be made from very immature plants, (samples cut on May 5,) but others cut at a later date, the (plants not yet in bud) do not show the same richness in albuminoids; and Mr. Harrington's series, Texas Bulletin No. 20, leaves it doubtful whether it be true, that the dry matter from very immature plants contains a higher percentage of proteids than that cut at a later stage of growth, but previous to the formation and ripening of the seed. The analyses of the leaves shows the proteids to be practically stationary from early bloom on, but to decrease after the plant has past full bloom.

We have treated so far principally of the compounds entering into the question of hay making and have selected our samples with the view of gaining information as to the best time for cutting, the influence of high or low land, and of irrigation. The results are tabulated below, being given on a hay or air dry basis. I have chosen to do this because such results correspond more nearly to the article with which our average reader is familiar than if they were reduced to the basis of dry substance. The results reduced to this basis may be found in the appendix. The statements made under the subject crude fiber seem pertinent to the other food constituents and the plant in general. The water in the hay does, as is clearly understood, make some difference; but it varies so little that its effect upon the relative results is negligible. The fats are present in comparatively small quantities, being equivalent to from 3 to 5.5 per cent. digestible carbohydrates and do not vary enough in the different samples to show clearly that the variations are due in any way to the stages of plant development; while the fat—ether extract—in Mr. Harrington's analyses (Texas Bulletin No. 20) is very much higher throughout than mine, and, in the irrigated alfalfa, shows a diminishing percentage as the season advances. The sample, which had no irrigation, shows the reverse. The fat content as shown by Mr. Voorhees's analyses (New Jersey

Rep. 1888), is also somewhat higher than mine, showing an average for hay, supposing it to contain 8 per cent. moisture, of 3.31 per cent., for drilled alfalfa and 3.02 per cent., for broadcast. The minimum is found in the third cutting, broadcast, with .53 per cent. As four cuttings were made they were probably cut quite immature. The percentage of fat, however, in Mr. Voorhee's samples agrees quite well with our farm samples, first cutting. None of the analyses show that there is as a rule more fat in the dry material of the very early cutting than in that of maturer plants.

Using the coefficients of digestion, 46 for crude fiber and 68 for nitrogen free extract, these being the average of the coefficients found by the New York and Colorado stations for the respective substances, we find the total digestive carbohydrates, neglecting the fats, to range between 36.41, as a minimum, and 40.51, as a maximum, or a variation of 4.1 per cent., including samples cut green, beginning bloom, half bloom, and full bloom, as well as the first, second and third cuttings. The proteids, as stated under this topic, appear to attain their maximum at the beginning of bloom and remain practically stationary until half bloom, or a little later, when they diminish rather rapidly. This period, during which the loss and the gain in the proteids is nearly equal, is the most advantageous time to cut for hay, both for quantity and quality, so far as the composition is a criterion. Hay possesses certain general qualities which make it acceptable to the animal and which are not dependent upon the composition. Many persons, I am informed, give preference to the second or third cutting for certain feeding. The composition of the respective cuttings shows but very little difference, the following figures giving the averages for each:—

	Ether Extract.	Crude Proteids.	Digestible Carbohydrates.
First cutting..	1.54	14.85	38.03
" " ..	——	13.98*	
Second cutting.	1.40	14.43	38.06
Third cutting..	1.46	13.03	39.15

The average precentage of proteids for the third cutting is based upon the two samples of hay, which alone, would not be sufficient, but the average for the samples from the farm department makes it only 13.47 per cent., and the results of Mr. Voorhee's analyses give, for the third cutting of hay, allowing 8 per cent. moisture, 13.67 per cent. These figures for the first and second cuttings are nearly

*Not including samples cut May 5th.

the same, with a slight difference in favor of the second cutting if we reject the very early cuttings (May 5th). This, however, is compensated for in part by the larger quantity of amids present. The third cutting is inferior in composition to either of the others. The following table presents, in tabulated form, the analyses of the different samples; first, those prepared by ourselves in the laboratory; second, those received from the farm department.

Laboratory Samples.

Number.	Number of Cutting.	CONDITION AT TIME OF CUTTING.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Amide Nitrogen.
1	1	Very immature	4.85	12.16	....	21.79	*22.56	.. ...	....
2	1	" "	5.15	10.64	....	19.95	*29.79	......	....
3	1	Not in bloom	4.17	10.21	1.94	15.60	35.17	32.91	.284
4	1	" " different locality from preceding	7.86	9.14	1.52	14.30	37.39	29.79	.187
5	1	Half bloom	6.04	9.30	1.19	14.41	36.54	32.50	.372
6	1	Full bloom, without irrigation	4 49	9.24	2.20	13.95	32.48	37.64	.176
7	1	Full bloom, low land	6.30	10.46	1.13	14.08	40.18	27.85	.230
8†	1	Full bloom, high land	7.14	9.94	1.40	14.54	36.39	30.59	....
9†	1	" " " "	7.46	10.19	1.54	14.83	32.27	33.24	....
10†	1	" " " "	3.77	10.99	1.40	15.22	35.51	33.11	....
11†	1	" " " "	7.60	11.34	1.67	15.92	31.96	31.41	....
12	1	Just past full bloom	8.87	9.94	1.40	14.54	36.39	30.59	....
13	1	In full seed	4.70	6.77	1.03	12.16	46.12	29.22	....
1	2	Not in bloom, without irrigation	6.48	10.51	1.46	16.40	28.66	36.49	....
2	2	Coming into bloom, upland	4.40	11.95	1.14	18.47	32.46	31.58	.517
3	2	Half bloom	6.61	9.91	1.18	16.11	37.24	28.90	.350
4	2	Half bloom	5.29	9.48	1.52	13.03	37.39	33.29	.614
5	2	Full bloom	4.31	10.97	1.76	12.88	38.06	32.02	.202
6	2	Half ripe, upland, with irrigation	7.24	8.92	1.99	12.08	30.99	38.79	....
1	3	Hay, College Farm	5.78	9.38	1.61	12.53	39.35	31.35	.100
2	3	Hay, Rocky Ford Station	6.08	10.28	1.31	13.57	34.67	34.09	....

LEAVES, ETC.

..	....	Leaves, with irrigation	4.93	11.48	2.96	23.33	13.15	41.16	....
..	....	" " "	4.63	14.29	2.94	24.33	13.12	40.70	....
..	....	" " "	8.40	13.60	4.10	22.18	10.67	41.05	....
..	....	" without irrigation	8.53	13.35	3.43	22.60	10.66	41.45	....
..	....	" " "	8.62	11.39	4.28	22.30	12.48	40.90	....
..	....	" half bloom without irrigation	8.38	11.39	4.28	23.31	12.48	40.60	...
..	....	" " " "	4.49	14.50	2.88	20.20	16.16	41.77	....
..	....	Plants past full bloom	4.52	14.51	3.05	20.20	16.16	41.72	....
..	....	Stems	5.41	4.91	.94	6.31	54 40	28.03	.070
..	....	Flowers	4.46	9.41	2.11	21.33	19.92	42.77	.692
..	....	Seed	6.35	3.19	14.41	29.26	9.35	37.04	....

* Not included in average.
† Samples 8, 9, 10 and 11 grown in drills.

Farm Samples.

Number.	Number of Cutting.	Condition at Time of Cutting.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Amide Nitrogen.
1	1	Individual plant	7.27	10.97	3.89	17.72	24.54	35.67	....
2	1	Individual plant	6.71	11.68	3.43	17.08	24.64	36.42	....
3	1	Hay, damaged	9.61	10.94	3.44	9.95	35.09	30.97	....
1	2	Individual plant	4.88	9.72	.82	12.15	34.59	37.84	....
2	2	Individual plant	3.71	10.31	1.17	12.29	38.08	34.43	....
3	2	Individual plant	11.61	11.26	1.69	15.26	29.07	31.11	....
4	2	Individual plant	11.75	10.63	2.43	16.26	26.16	32.77	....
1	3	‡ Sample, Field D	6.28	10.29	1.93	15.83	28.89	36.78	....
2	3	Prime hay	4.71	9.94	1.24	12.01	37.29	34.81	....
3	3	Prime hay	5.58	9.94	1.11	12.57	34.91	35.84	....

‡ Sample somewhat charred in drying.

ALFALFA AND CLOVER HAY COMPARED.

The plants from which these hays were cut, were growing side by side under identical conditions, were cured in the same manner, and are comparable in every respect. The clover was very vigorous; the flowers were very nearly half turned; the stems were stout, but leafy; and the whole plant was in prime condition. The hay was cured in a sack as before described in the account of the preparation of our alfalfa samples. A sample of alfalfa also in prime condition and in half bloom is chosen for the comparison. The green clover yielded 24.25 per cent. of hay, and 75.75 per cent. of water, and the alfalfa 26.94 per cent. of hay and 73.06 per cent. of water.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Amide Nitrogen.
Clover, heads half turned	5.36	10.17	1.88	13.43	28.97	40.20	.155
Clover heads, half turned	5.22	9.97	2.03	13.43	28.83	40.53	....
Water free substance	....	10.75	1.99	14.18	30.61	42.46	....
Water free substance	....	10.52	2.15	14.18	30.42	43.74	....
Average, water free	....	10.63	2.07	14.18	30.52	43.10	....
Alfalfa, half bloom	6.04	9.30	1.19	14.43	36.54	32.50	.372
Alfalfa, half bloom	6.29	9.33	1.51	14.43	36 38	32.06	....
Water free substance	....	9.89	1.26	15.37	38.88	34.60	....
Water free substance	....	10.06	1.61	15.37	38.53	34.43	....
Average, water free	....	9.98	1.43	15.37	38.71	34.51	....

The coefficients of digestion for good quality clover hay is given, in Massachusetts State Experiment Station Report for 1893, as 48 for crude fiber, 49 for proteids, 43 for ether extract, and 58 for nitrogen free extract; and for alfalfa, 46 for crude fiber, 73 for proteids, 51 for ether extract, and 68 for nitrogen free extract.

One hundred pounds of this clover hay contain, when perfectly dry, 47.49 pounds digestible food, of which 6.95

pounds is proteids, while the alfalfa furnishes 54.43 pounds digestible food with 11.22 pounds proteids. The green alfalfa crop yielded in this case almost 2.5 per cent. more dry matter, which contains about 7 per cent. more digestible food than the clover.

ALFALFA, RED CLOVER AND PEA-VINE ENSILAGE COMPARED.

The loss in making alfalfa hay, together with other considerations, has led to some experiments in making alfalfa silage. The following samples were received, one in late summer and the other in late winter. The condition of each was considered good, and cattle were reported to eat them freely, even in early fall when they had access to green pasture. The average dry matter, as determined in three samples, is 30.19 per cent.

Sample No. 1—Farm Department—Silage made from first cutting :—

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.
1. Alfalfa Ensilage	8.98	13.19	2.93	14.18	30.77	29.95
Water Free	....	14.46	3.22	15.57	33.49	33.25
2. Alfalfa Ensilage	2.21	11.91	1.19	17.63	36.06	31.00
Water Free	....	12.19	1.22	18.02	36.89	31.70
3. Pea-vine Ensilage	4.71	14.91	3.24	10.95	30.06	36.13
Water Free	....	15.63	3.40	11.03	31.39	38.54
4. *Red Clover Ensilage	....	9.30	4.10	15.00	29.90	41.70

*Expt. Sta. Bul. No. 11, p. 52.

These samples of ensilage were in good condition when received at the laboratory. The alfalfa silages, particularly No. 2, had a marked disagreeable odor and taste ; the pea-vine ensilage was bright, with an agreeable odor and a pleasant acid taste. Mr. Empson, of Longmont, through whose kindness this sample was furnished, informs me that the vines used in making silage are of varieties grown by their company for canning. The peas are threshed out and the vines are put in silos and subsequently fed to sheep or lambs. The vines are cut when the crop is in best condition for canning. It is evident that this pea-vine silage is poorer than pea-vine silage would be by whatever of nitrogen, etc., is removed in the peas. The ash in the pea-vine silage is really not so high as appears in the analysis. It amounts to 8.96 per cent., after the deduction of sand. It

will seldom be advantageous for the farmers of this country to make their alfalfa crop into ensilage, but if they should choose to, the ensilage produced, as shown above, will compare favorably with a very good quality of alfalfa hay, and is quite as well adapted to this use as red clover or pea-vines. Alfalfa, when stacked with a great deal of moisture in it, sometimes passes through a fermentation, producing a hay which may be considered as intermediate between alfalfa hay and ensilage. In the cases which have been called to my attention this result has been obtained by accident, and, of course, without special care or extra labor. This is very near to the so-called brown hay; its color is reddish and it is a very agreeable fodder to cattle.

As to the digestibility of either the ensilage or of this red or brown hay, I find no data; but cattle fed on either are said to thrive admirably, and it seems probable that the digestibility in these cases does not differ materially from that of the field-cured hay. In making alfalfa ensilage, the silage must be carefully protected from the influence of conditions producing further changes than those producing the ensilage fermentation. The following analysis of damaged ensilage will enforce this statement:

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.
Damaged Alfalfa Ensilage	5.90	17.89	2.34	15.47	46.18	12.22
Water Free	....	19.01	2.49	16.41	48.90	13.19

The decrease in the percentage of nitrogen free extract and the increase in that of the ash and crude fiber are equally noticeable.

What the loss of dry matter was in either of these cases I do not know. Storer, in his Agricultural Chemistry, quotes the loss of dry matter in making alfalfa ensilage at 27 per cent. The amide nitrogen was not determined in these ensilages, and, while it is known that there is a retrogressive change in the nitrogenous compounds in making ensilage, I have no data on which to base an approximate estimate of the loss of these in either of the preceding instances. The damaged ensilage is richer in total nitrogen than the prime ensilage, No. 1, and the nitrogenous compounds seem to have changed slowly; this, however, is sub-

ject to modification, due to the formation of amides; also a small amount of ammonia from the albuminoids.

ELEMENTS OF PLANT FOOD TAKEN FROM THE SOIL.

The leguminous plants, to which order alfalfa belongs, store up in their stems a large amount of nitrogen which they are believed to obtain largely from the atmosphere, and for this reason they are considered as nitrogen gatherers, adding to the soil more nitrogen than they draw from it, provided the plants are not removed, but fall where they grow or are plowed under. But, when the hay is taken off the field, the problem is a different one, and whether it adds to the nitrogen in the soil or takes from it, depends upon the ratio of the nitrogen in the leaves and stems which fall and decay upon the soil to that taken from the soil proper in the form of nitric nitrogen. As I know nothing of the value of this ratio, I am compelled to content myself with the general results which are well known ; still, under the discussion of the roots, we shall see that there are reasons why we are justified in doubting whether the store of nitrogen in the soil is added to by growing alfalfa ; on the contrary, while this plant is provided with tubercles—micro-organisms which enable it to appropriate atmospheric nitrogen—it is also a greedy feeder upon the soil nitrogen.

The benefits which accrue to soils cropped to alfalfa are unquestionably great, but whether they are lasting, or call for a quick rotation in order to be maintained, is still to be established. The case of the other elements of plant food is not involved by any compensation as in the case of nitrogen ; but every pound taken away is at the expense of the supply in the soil. As our soils have not been under crops of any kind very long, and to alfalfa only a short time, it is a reasonable assumption that the average mineral constituents of the ash correspond very nearly to the requirements of the plant. The quantities given by our analyses, representing plants supplied with an abundance of available food, are probably high enough.

The accompanying table gives the ash constituents taken from the soil with every 1,000 pounds of hay. The sand, carbon, and carbonic acid are rejected in this table. There may appear to some to be a discrepancy between the table as given on page 31, and the following; the two are, however, the same as concerns the following subtances contained in the ash:

POUNDS PLANT FOOD PER 1,000 POUNDS ALFALFA HAY.

Cutting.	Condition of Plant.	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Lime.	Magnesia.	Iron Oxide	Alumina.	Manganese Oxide.	Potash.	Soda.	Total.	Nitrogen.
1	Green...........	1.158	4.923	4.349	9.655	22.352	3.159	.371	.159	.163	29.720	1.174	77.183	24.96
1	Green...........	1.006	4.031	4.323	5.169	21.528	3.314	.386	.147	.109	25.848	1.237	67.098	22.89
1	Half bloom.....	.924	4.105	4.418	3.865	21.690	3.343	.295	.165	.109	26.078	1.434	66.426	23.08
1	Half bloom.....	1.404	4.138	5.230	6.288	22.182	5.523	.369	.235	.174	22.209	1.708	69.461	21.40
1	Full bloom.....	.813	4.839	5.182	10.052	25.522	3.509	.248	.083	.156	22.398	.869	73.671	23.16
1	Full bloom.....	1.808	4.015	3.412	6.829	25.647	3.776	.074		.064	28.137	.857	74.619	22.53
1	Full seed.......	.706	3.474	2.705	4.851	12.934	2.864	.261	.157	.155	17.985	2.586	48.678	19.46
2	Begin'g bloom..	.917	4.709	7.306	10.359	31.038	4.031	.360	.066	.230	30.324	2.223	91.563	28.91
2	Half bloom.....	.631	4.812	7.356	10.174	26.626	3.824	.259	.109	.156	27.930	1.838	83.715	25.89
2	Full bloom.....	.919	4.882	7.194	10.541	28.390	4.358	.363	.186	.205	26.076	1.073	84.187	20.61
2	Past full bloom.	1.353	4.238	4.257	8.428	27.426	4.124	.115		.084	10.643	.948	70.616	20.85
3	Hay.............	.402	3.397	3.087	40.839	18.694	3.605	.175	.081	.107	24.693	4.255	63.335	18.95
..	Red clover......	1.831	3.661	1.260	2.573	23.778	5.227	.102	......	.203	25.160	.223	64.018	21.49
..	Flowers	2.971	7.248	5.887	4.593	15.948	3.720	.957	1.110	.191	24.076	3.787	70.487	34.12
..	Leaves..........	2.673	4.367	16.704	7.009	45.425	7.626	.821	.814	.317	13.196	5.396	104.348	31.77
..	Leaves..........	1.009	5.114	13.062	8.665	33.042	5.395	.344	.273	....	21.277	4.411	92.592	35.68
..	Leaves..........	1.048	4.661	9.381	10.906	52.569	5.839	.602	.141	.266	15.846	1.062	102.221	35.49
..	Leaves..........	1.159	4.900	15.356	8.490	50.488	6.425	.610	.139	.447	15.447	5.157	108.618	38.92
..	Stems...........	.790	2.198	1.711	2.934	7.002	2.563	.225	.233	.082	13.184	4.110	35.032	10.09
..	Stems...........	1.099	3.039	2.392	4.102	9.768	3.604	.328	.334	.112	18.394	5.710	48.882	......
..	Stems...........	.731	3.769	1.297	6.381	9.117	2.915	.340	.183	.098	20.817	2.813	48.461	......
..	Stems...........	1.015	3.272	1.254	6.525	11.671	2.871	.239	.244	.097	24.159	.721	52.068	......

These results show that, with each ton of first cutting hay, there is removed an average amount of 143 pounds of ash constituents; with each ton of second cutting hay, 165 pounds; and with the third cutting, 127 pounds per ton. Our sample of red clover gives 128 pounds against 143 pounds for the alfalfa. The following are the amounts of the most important plant foods taken from the soil and air by the successive cuttings of alfalfa and red clover hay per ton of 2,000 pounds:

	Nitrogen.	Phosphoric Acid.	Potash.	Sulphuric Acid.	Chlorine.	Lime.	Magnesia.
First cutting..............................	46.00	8.69	51.46	8.97	13.95	46.40	7.54
Second cutting..........................	48 13	9.32	51.99	13.06	19.75	56.74	8.17
Third cutting	37.90	6.79	49.39	6.17	8.16	37.39	7.21
Average for alfalfa hay	44.01	8.27	50.95	9.40	13.95	43.51	7.64
Alfalfa in full seed	38.92	6.95	35.97	5.41	9.70	25.87	5.73
Red clover, heads half turned...........	42.98	7.32	50.32	2.52	5.15	47.56	10.45

This table gives the amount of plant food removed by a ton of average hay; but if the amount removed by an average crop is desired, we have taken 1.65 tons for first

cutting, 1.2 tons for the second cutting, and 1 ton for the third cutting. This is estimated on a yield of 3.8 tons for the three cuttings, which is not far from the average crop. This correction changes the total amount of mineral matter removed from 167.23 to 169.26 pounds. Actually weighed crops seem not to be of record in such numbers as to give them value as a basis. That four, five and more tons have been cut per acre, is not doubted, but such yields are not the rule. The land of the Rocky Ford Station has yielded a trifle over five tons and so has land near Loveland, in this county, and doubtless at many other places, but these are large and not average yields. Estimated yields are seldom too low and measured tons are only approximately correct, but they serve a good purpose when nothing better is available. Adopting the judgment of sixteen farmers of Colorado, some of whom are known to the writer as practical and conservative men, we make the average yield 3.7 tons per acre. Mr. A. A. Mills, of the Utah Station, makes the yield from measured areas 4.24 tons per acre. These figures seem exceedingly conservative when compared with many current estimates, but they are fully high enough for the average crop and close approximations to its upper limit.

ALFALFA SEEDS.

The ordinary analysis of the seed is given in the table on page 31, and the ash analysis in the appendix. The fat or oil—ether extract—was determined by both my assistant, Mr. Ryan, and myself. Mr. Ryan obtained 14.41 per cent. and I 14.04 per cent. Mr. Ryan extracted his portions for many days; I extracted mine for eight hours. There seems to be a volatile portion, which gave Mr. Ryan trouble in determining the moisture.

AMOUNTS OF SEED COMMENDED FOR SOWING PER ACRE.

The practice followed by many intelligent farmers of selling the good seed and sowing the screenings, led us to make the following experiments, even though they digress from the main purpose of this bulletin.

The fresh seed has a light greenish yellow color which is sensitive to the light, eventually becoming reddish brown. The size of the seed varies; it is described as larger than clover seed. A sample gathered by hand from plants growing singly on a poorly irrigated piece of ground, had the following properties: bright greenish yellow color; more than twice as long as broad; and as a rule not as thick as broad; thicker at one end than at the other, giving the seed a slightly twisted appearance; length a little more

than 3-32 of an inch. The pods were full, the seeds pressing one upon the other. The analysis of these seeds is given in the table. When well dried the seeds absorb moisture readily. Fifteen portions of one gram each were weighed off, after thoroughly shaking the sample, and counted. The average was found to be, 456 seeds to the gram; lowest number per gram, 450; highest number 463; number of seeds per pound, 206,837.

Sample No. 2, purchased in the market, gave 458.6 seeds per gram; 208,021 seeds to the pound. These seeds were not so even in size as the first sample. There were a few shrunken seeds. The sample was clean, containing less than one per cent. by number of foreign feed. Sample No. 3, also purchased in the market, was of a brownish yellow color; sample contained 8 per cent., by number, of foreign seed, mostly of an amaranthus. The average number of seeds to the gram of this sample was 504.46. The seeds were very even in size; minimum number to the gram, 503; maximum, 505. The number of seeds to the pound was 228,818.

Sample No. 4, consisted of first quality screenings, furnished by J. E. Gauger, Rocky Ford, Colo., about 65 per cent. of which was immature when cut. The seed was shriveled and dark brown in color. The sample was quite free from grass seeds, weed seeds, and stems, and contained 259,340 seeds to the pound.

Sample No. 5, first quality screenings from the same source as No. 4, was dark and contained many shriveled seeds, in which by weight there was 23 per cent. of impurities—grass and weed seeds. This sample contained 344,123 seeds to the pound.

Sample No. 6, first quality screenings (J. E. Gauger) seed evidently well cured, many seeds green and immature, contained 266,233 to the pound.

Sample No. 7, second quality screenings (J. E. Gauger), containing more stems and weed seeds, especially of an amaranthus, than any other sample, contained 331,383 seeds per pound.

Sample No. 8, third quality screenings (J. E. Gauger), was quite clean. The seeds were large, but shriveled, numbering 312,385 to the pound.

We may assume that a pound of first-class seed contains 210,000 seeds; first quality screenings, 260,000 and occasionally many more on account of shriveled seeds; and for second and third quality screenings, about 320,000 seeds to the pound.

THE QUESTION OF WHAT IS A GOOD STAND.

The amount of seed sown to the acre in this state varies exceedingly, the smallest that I know of as having been sown for a hay crop, being seven pounds per acre; and having examined the stand personally, I have no doubt but that it will produce as large a crop as a heavier seeding would, but whether there is the same certainty of getting an even stand is a question. In this case it was very even. The highest amount that I have seen given as sown to the acre is thirty pounds. Twenty and twenty-two pounds to the acre is common. This gives us, supposing prime seed to be used, from 1,470,000, with seven pounds, to 4,620,000 seeds when twenty-two pounds of seed are sowed to the acre. There is certainly a wide difference in practice, and it is claimed, with no difference in the result, either in quantity or quality of hay. The majority is unquestionably in favor of heavy seeding, but the minority seem to me to have more reason on their side.

The quantity of seed to be sown to the acre was touched upon by Miller (1807). "In sowing broadcast Rocque directs fourteen pounds to the acre; in Kent they sow twenty pounds, which is generally allowed to be the proper quantity; in France they allow near thirty pounds to an English acre. Some sow only ten pounds with six pounds of broad clover, to have a crop the first season, both with a thin crop of barley or oats." Again, he says: "The field was sown broadcast with Lucern seed. * * Twelve pounds to the acre sown at twice." And of another field of broadcast Lucern sown twenty years before with barley. "The plants were in patches or single, often two or three feet apart; yet it produced four tons of hay on an acre, at three cuttings. * * * It also shows what a large space plants of Lucern will fill."

Two reasons can be urged in favor of heavy seeding, and if they are founded on facts, they are sufficient to justify the practice. One is that a thick stand produces a more desirable hay than a thinner one; the second is that a large amount of seed is necessary to obtain such a stand. In the first proposition there is clearly a lack of definiteness in the term "a thick stand." Very few persons who use the term have any idea whether they mean by this one or twenty plants to a square foot, and I doubt whether there is any increase of crop or quality of hay gained in one field with 260,000 plants to the acre over another with one-half that number, assuming that the stand is equally even in the two fields and that other conditions are similar. This is six and three plants to the square foot respectively.

We have given ourselves some trouble to establish some thing definite regarding the terms stand, good stand, etc., in connection with the weight of stubble plowed under.

A piece of alfalfa, six months old, contained fifteen plants to the square foot, or 653,400 per acre (Prof. W. W. Cooke), which is one plant for every seven seed on the basis of twenty pounds of seed to the acre. A measured piece, twenty-five feet square, was plowed up and the plants picked out of each furrow in turn, the whole of the soil being turned over by hand, and the number of plants to the acre was found to be 526,793. Prof. A. E. Blount writes me that this field was seeded to alfalfa May 10, 1886, and was consequently ten years old. The roots were very small, not over one quarter of an inch thick at the crown, and were in a remarkably healthy condition. This portion of ground is as high as any other cultivated portion of the college farm and is a fine, loamy soil. The yield last year was rather over four tons (weighed) per acre.

Mr. Philo K. Blinn, Superintendent of the Rocky Ford Experiment Station, in Otero county, at my request, measured off a square twenty-five feet on the side and counted the plants. He found 139,392 to the acre. This is a most excellent piece of land, alluvial soil. The yield of alfalfa hay last year was 4.4 tons per acre. Mr. Blinn measured two small squares, 5x5 feet, obtaining 291,000 and 305,000 plants in these.

I selected an average plat 25x25 feet in a field one year old seeded with twenty-two pounds of seed to the acre, cross drilled 11 pounds each way. The soil is a fine loam, subsoil sandy clay succeeded by fine sand. This plat has been in cultivation a number of years. The stand would be designated as "very good." The cross drilling showed plainly at this date, April 29. Number of plants per acre, 331,122.

A piece 25x25 feet of another field, sowed to alfalfa May 17, 1884, twenty pounds of seed to the acre, (Prof. A. E. Blount), was plowed up. This field of alfalfa is in bad condition. The stand is very irregular, large patches of ground being entirely bare. The soil is a sandy loam, with clay subsoil; water plane four to eight feet from the surface. Number of plants per acre, 70,283. Nearly every plant has a hollow crown and root; yield per acre last year something over three tons. At three tons this is approximately 1 1-4 ounces of hay or less than 4 1-6 ounces green weight to the plant for the season. In the case of the 562,-793 plants and four tons yield, it is only 1-4 ounce of hay to the plant, or one ounce of green weight for the three cut-

tings. I sought out twenty plants growing singly, which had received no care whatever. They were in patches of volunteer plants. The weights were taken immediately upon cutting and averaged 14.4 ounces or 3.8 ounces of hay to the plant. The average number of stems was 39 to the plant; the highest number was 58. The lowest weight was about 1-3 of a pound, the highest 2 1-3 pounds. Any one familiar with alfalfa will recognize that these plants can be duplicated easily and are by no means unusually large. I found a plant standing quite by itself in the field of James Whedbee, the space in which the plant grew being about three and possibly as much as four square feet. There arose from the crown of this plant 161 stems. I dug up one other plant, which had 360 stems on it; the space covered by this crown was about three square feet. The weight of these I regret was not determined. Others have observed even larger plants. Miller says that he had a plant whose crown was eighteen inches in diameter, and from which he cut nearly four hundred stems at one time. M. Duhamel states that a flourishing plant will produce a pound of well dried hay. These facts seem to me very suggestive. I have noticed with some degree of attention the size of the stems on these large plants and I do not find them of noticeable coarseness. I believe that every advantage supposed to be obtained by crowding the plants, whether the claim be well founded or not, will be produced with an even stand of not more than four plants to the square foot, and of two or even one under favorable conditions. The importance of favorable conditions is admirably shown by the yields of the plat giving 526,793 plants per acre. In 1893 it yielded 2 2-5 tons at the first cutting; this year about one ton. Moisture is necessary to the production of a crop of alfalfa. I regret that we have no analyses of hays cut from crowded and from singly growing plants. Granting, however, that a stand of a half million plants to the acre is desirable, is so large a quantity of seed as twenty pounds, about 4,200,000 seeds, necessary to produce it? This will depend first of all upon the germinating power of the seed, and also upon the vitality of the plants produced.

VITALITY OF ALFALFA SEED.

It is claimed that alfalfa seed soon looses its germinating power, and that the young plants are very tender, though hardy enough when established and older. Concerning the former, Loudon says: "Great care should be had to procure it (Lucern seed) plump and perfectly new,

as two years old seed does not come up freely." In North Carolina Bulletin No. 60, these seed are described as twice as large as red clover seed with a brownish yellow hue. "The vitality of Lucern seed is so low that seed over one year old is scarcely worth sowing." The author of that bulletin records two sprouting experiments made with presumbly two years old seed, showing only 6 and 12 per cent. of the seed capable of germinating. This is quite in accord with the statement of Loudon. Not finding myself able to unhesitatingly subscribe to these results, I collected the following samples of seed. I experienced difficulty in obtaining in our local markets seed two years old, even after explaining my desire and object.

1. Prime seed, two years old, gathered by myself.

2. Prime seed, two years old, obtained in market fresh and kept in laboratory.

3. Prime seed, obtained of P. Anderson & Co., probably two years old.

4. Prime seed, two years old, grown in Otero county, (J. E. Gauger).

5. Prime seed, three years old (J. E. Gauger).

6. Prime seed, six years old, obtained from Professor Crandall, whose record shows that this seed was obtained from P. Henderson & Co., of New York, through the Department of Agriculture at Washington, D. C., in the spring of 1891. This sample had been kept for most of this time in a 2-oz. bottle, exposed to the light in a show case. The seeds were discolored, reddish brown, and emitted a rancid odor when poured out for the purpose of mixing. I, of course, have no record of the variations in temperature to which these seeds had been subjected, but they were certainly great. Their state of moisture varied, also, but probably less than any other external condition.

7. Screenings, first quality, one year old, (J. E. Gauger).

8. Screenings, first quality, two years old, (J. E. Gauger).

9. Screenings, first quality, three years old, (J. E. Gauger).

10. Screenings, second quality, two years old, (J. E. Gauger).

11. Screenings, third quality, one year old, (J. E. Gauger).

The following tests of these seeds were made with such facilities as are at the command of every farmer. A common tumbler was filled with crumpled paper to about half its hight and pressed down until it was quite even. On this were placed three disks of ordinary blotting paper; the

seed were strewn upon the upper one of these disks and covered with two similar disks of blotting paper and one of cardboard. The crumpled paper was thoroughly wetted, the disks and seed put in place, and enough water added to fill the bottom of the tumbler to the depth of about half an inch, and placed on a box behind the sitting room stove. The water that evaporated had to be replaced, and required the addition of a tablespoonful night and morning. The tests were continued for fourteen days; the record is as follows:—

RESULTS OF SPROUTING EXPERIMENTS.

No. of Sample.	QUALITY.	Years Old.	Number of Seeds to the Pound.	Seeds Taken.	Seeds Rotted.	Seeds Left.	Seeds Sprouted.	Average per cent. Sprouted.
1	Prime seed.....	2	206,837	100 100	0 0	0 8	100 92	96.0
2	Prime seed..............................	2	228,818	100 100	1 0	9 6	90 94	92.0
3	Prime seed..............................	2	208,021	100 100	1 1	7 0	92 99	95.5
4	Prime seed..............................	2	....	100 100	1 5	13 5	86 90	88.0
5	Prime seed..............	3	....	100 100	0 0	2 1	98 99	98.5
6	Prime seed..............................	6	....	100 100	5 5	1 3	94 92	93.0
7	Screenings, first quality	1	259,340	100 100	23 20	11 13	66 67	66.5
8	Screenings, first quality	2	344,123	100 100	42 29	7 11	51 60	55.5
9	Screenings, first quality	3	266,233	100 100	24 16	1 1	75 83	79.0
10	Screenings, second quality.............	2	331,383	100 100	59 53	7 5	34 42	38.0
11	Screenings, third quality	1	312,385	100 100	66 48	1 5	33 47	38.5

The seed designated as "left" or hard seed, make from 1.5 to 9 per cent. of the samples of prime seed and from 1 to 12 per cent. of the screenings. These seem not to imbibe water for a long time, but eventually they do when they swell and sprout in large numbers. The hard seed remaining at the end of the sprouting tests were put together and the test continued for an addional twenty days, when 78 per cent. of them had sprouted, 13 percent. rotted, and 9 per cent. were still left. This explains, in part at least, the observations that some alfalfa seed seems to lie dormant for a time.

The sprouting tests were continued for from 13 to 16 days, but a sufficiently accurate estimate of the germinating

power of the seed could have been formed by the end of the third day, as the following shows :—

THE NUMBER OF SEEDS WHICH HAD EITHER ROTTED OR SPROUTED AT THE END OF THE THIRD DAY.

			Per cent.
Prime seed, two years old			87.00
Prime seed, six years old			80.50
First quality screenings,	one year old		84.00
" " "	two " "		85.00
" " "	three " "		85.00
Second " "	two " "		85.00
Third " "	one " "		93.00

There is a considerable difference in the readiness with which the different samples of the same age germinate, more even than between samples of different ages. The quickest of the eleven samples to germinate was the one six years old. The results are positive in showing that the age of the seed up to six years old does not effect their germinating power. In regard to the vitality of the plants produced, I have made no observations, but so far as I could judge from the vigor with which the seeds sprouted, I would say that it depended upon the seeds themselves rather than upon their age; the seeds of some samples being obviously stronger than those of others, and each sample showed this difference between the individual seeds.

These tests and observations also strengthen the claim made that in practice screenings produce as satisfactory results as prime seed. Taking it on the basis of the germinating power in the most unfavorable sample, second quality screenings two years old, with only 38 per cent. germinating, we have, where twenty pounds of seed are sown to the acre, 1,325,532 plants, and assuming that one-seventh of them live, there would be 189,361 plants to the acre, or over four to the square foot, a sufficient number surely to produce a maximum crop. It sometimes happens that it is necessary to re-sow a field the second year, even with twenty-two pounds of seed per acre. Such failures are not due to the quantity of seed nor to the germinating power. I do not believe that it would happen oftener with eleven pounds to the acre than it does with twenty. It is not my province to seek the causes of such failures, but I think I have adduced sufficient proof that it does not lie in the germinating power of the seed.

ROOTS OF ALFALFA.

That this plant is an exceptionally deep rooting one, has been recognized by every writer on the subject, as is evi-

denced by the statements to be found scattered through the literature on this subject ascribing a length of ten, fifteen, thirty-five, and even more feet to its roots. The popular estimation of their length has been and is equally appreciative of their power to penetrate to considerable depths. The size attained by the roots has also been stated to be large, but the writer does not recall having seen any figures given to convey a definite idea of the size actually attained under stated conditions of soil, age of plant, cultivation, etc., but rather that the root is a tap root, large and fleshy, "resembling a carrot" more or less,or is represented as forming a symmetrically formed but inverted cone, in which system the tap root is, as a matter of course, the longest and central portion or axis.

The size of alfalfa roots is not so great as the usual adjectives used in describing them would lead one to infer. It is a strong root, but is under one-half inch in diameter, rather than above it. This statement is true of the plants when grown in a deep, sandy loam, under favorable conditions as to irrigation and climate, including mild winters. Larger roots have been observed by the writer, but there have been special conditions obtaining wherever this has been the case and these roots represented the size which the alfalfa root may attain, and not the average size which they actually do attain when growing in ordinary soil, and standing thick enough to produce, say 3 1-2 tons of hay per acre, with three cuttings annually. The largest root measured by me, was 2.82 inches in diameter, being nearly circular in section, though not quite ; its largest diameter was rather more than three inches. An examination proved that this was an anomalous root. For some reason, not discovered, the tap or central root was short, not exceeding 1 1-2 feet, at which point it divided, giving rise to several rather small branches which were not followed as they spread out, running several feet almost horizontally. This dividing could not be attributed to the roots having encountered a hardpan or other obstacle, for the soil at this depth was uniform in hardness above and below the point of spreading. I have seen several very large roots, but have found upon digging them out, that they were in every case short and at variance with what seems to be the normal type.

The root system of this plant, growing in our soils, is exceedingly simple and is shown in the plates. The roots represented, are from three different counties, the soils varying from sandy loam to heavy clay. They show a marked permanency in type of development in a

simple tap root, running down to from three to five feet and then sending off a few side roots, or rather dividing into a few branch roots about equal in size and length. These branches do not, as a rule, deviate more than a few inches from the course pursued by the tap root before division. I have in no case found a system of small roots starting out below and near the crown, extending laterally for several feet and then turning downward, forming a symmetrical conical system, whose broadest part was near the surface. The absence of such roots was a matter of note to me, but after having observed it in upwards of three hundred and fifty instances, I was satisfied that it was a habit of the plant. In cases where I found any root or roots setting out from the tap root immediately under or near the crown, they were large, usually as large as any of the roots formed by the branching of the tap root, and in every instance in which I was able to follow them to the end, they extended to almost or altogether as great a depth as the tap root itself or any of its divisions. When such side roots occured, we found but few of them, as a rule only one or two. This is well shown in one of the plates. The tap root, as well as all its divisions, are remarkably smooth and free from fibrous roots. The tap root is often perfectly smooth, save for the wart-like excressences on it, caused by its symbiotic micro-organisms; so much so that it can be removed after having been properly exposed, leaving a perfect cast of the root in the undisturbed soil. Close investigation of the adjacent soil has failed to show small roots even a few inches in length, such as may be found practically possessing the ground for many inches—twenty or more—about the vetch, tomato, or almost any of our garden plants. It may be stated here that the plants studied had not been cultivated, that is, the soil about them had not been disturbed from the time the seed was planted until the plants were dug up, except in cases where the fact will be explicitly mentioned.

The absence of these small fibrous roots has been and still is perplexing, as it was anticipated that such a vigorously growing plant would be well supplied with such, each provided with its spongiole to provide the plant its necessary sustenance. While the number of spongioles found was in the aggregate large, it was much smaller than expected and the spongioles were at the extremities of the roots themselves and almost exclusively at a depth corresponding to that attained by the root. This observation is in perfect accord with the usual statement that alfalfa is a

deep feeder and furnished a very convenient explanation for the observed effect of an alfalfa rotation upon an exhausted soil; but it is contrary to another fact which has also been observed, i. e., that alfalfa responds quickly to top dressings of fertilizers, barnyard compost and ashes being the fertilizers here referred to. Other fertilizers may produce equally quick and marked effects, but reliable observations have been made with these two. The spongioles were found mostly at or near the depth reached by the tap root. The form and size of it varied greatly. It was as a rule cylindrical, from one to one and a half inches long and terminated by a rather stiff hair-like projection. The root leaving it was much smaller than the spongiole for several inches behind it, and, consequently, was growing in a free space made by the extending spongiole. The amount of work done by the plant in this manner is very great. While the cylindrical form prevails, others also occur, a double cone shape being quite common. As already intimated, these were not found in large numbers near the upper part of the roots; and at no other point except where the softness of the ground and a greater abundance of food encouraged their development. Such conditions were found, for instance, in refilled prairie-dog holes which were always crowded with them and in places very thickly so.

THE DEPTH ATTAINED BY THE ROOTS.

The depth to which the roots penetrate and at which they feed varies, as a matter of course, with the soil; and in cases where the permanent water table lies within twelve feet of the surface, with this also, as the roots do not according to my observations enter the water for a greater distance than from four to eight inches. The popular notion that the roots cannot endure the water, but cease to grow and decay as soon as they reach it, is not substantiated by observation. They do cease to extend further downward, but all that I have had opportunity to observe were healthy and vigorous. I entered the permanent water plane at two localities where I dug out the roots. In one instance the water was alkaline (Jas. Whedbee's place, 1½ miles from Fort Collins); in the other (Rocky Ford, Otero County) the water, an analysis of which will be given later, was as bitter as a solution of Epsom salts. The roots, however, penetrating it were not dead. In the former case the water was only six feet seven inches and in the latter twelve feet from the surface. The roots do cease to descend, as would be expected, when they reach permanent water; but they do not on the other hand continue their downward growth under

all circumstances until they reach permanent water. In choosing a place at which to dig up alfalfa roots, several things had to be considered, especially as my original plan was, after having found plants of some age, to make an excavation of sufficient size and depth and then to remove the plants by washing away the soil. I succeeded in finding the plants and water favorably located, but a little examination of the manner in which the soil had withstood the action of the waste water from an irrigating ditch suggested that it would be utterly impractical to wash out the roots; and this was the case. The site chosen was about twelve miles from Fort Collins, on the place of Mr. J. H. Walter, in Weld county, at a point where a ditch had been cut through a hill, making a cut at the deepest point of rather more than twelve feet with a flume crossing it at this point. The lake, or reservoir which the ditch had been cut to empty had not been filled, so I was informed, for several years and the soil at the bottom of this cut had had no other than rain and snow water to wet it in that time. I do not know at what depth the water plane lay at this point; but unless the water plane was somewhat above the level of the water in the lake near by, which, after making allowance for the damming back of the water in the soil, seemed to me very improbable, it must have been a good way below the bottom of the cut, so that the roots had most favorable conditions to seek it if they did not get enough moisture otherwise. These plants were either five or six years from the seed, were growing a few feet from the edge of the cut, were exceptionally vigorous, and were at that time in full seed, not having been cut that season. I do not know how much water they had received, but judging from the condition of the corn and alfalfa growing within a few feet of them, the supply had not been very liberal, and I inferred that they owed their luxuriant growth to the fact that it had probably been made during the time of early rains and to their advantage of position, in that they were growing in a little sag in the surface of the ground. A section of this soil was as follows: about three inches of blown dirt, leaves, dead stems, etc., from previous years; in other words, soil made about the plant subsequent to their establishment there; then followed twenty-one and a half inches of a black, compact soil which had not been disturbed by the plow except very superficially. This was so firm and tough that it had to be removed with a pick. Succeeding this was six inches of a white marl; next a calcareous clay, three feet; then a hard, tough clay of three inches, followed by a rather sandy clay of three feet thickness; and then a second band of tough, hard clay, three

inches; and lastly a fine sand. This soil from top to bottom was only slightly damp, and the sand and sandy clay in the bottom of our excavation was as dry as any portion of it except the very top. These roots were the largest that I have ever seen anywhere and supported the most luxuriant growth of tops. The crowns were large and the stems were very tall, measuring five feet three inches. The streaks of hard clay had not caused the roots to spread out and seek the contact between it and the softer soil, but it had caused them to double upon themselves, to twist and knot, and then run horizontally for some inches when they changed their course and descended again. It was almost as difficult to get them out of this without cutting or breaking as it had evidently been for them to make their way through it. I did not observe a single instance in which the root had divided in penetrating these hard layers. These plants sent their roots down eleven feet nine inches, with their ends, for the most part, in a fine sand; but the deepest ones were in a sandy clay where they would have had comparatively little work in penetrating to a greater depth, and it was not the abundance of moisture which caused them to cease growing.

The next place where I undertook to dig up roots was between an irrigating ditch and a railroad cut. Quite a large quantity of clay had, at a previous time, been taken from this point for the manufacture of brick. The character of the soil was almost the same from the top to the bottom; here the roots, were not gnarled as in the preceding instance, and they attained a length of twelve feet three inches, with their ends in soil just as dry as that through which they had passed. Though these roots were longer by about six inches than those from Mr. Walter's place, they were much smaller,their diameter being not more than two-thirds of that of the former; but they were still above the average. The age of these plants was either six or seven years. These are all the observations that we have had opportunity of making upon the effect of the depth of the water plane upon the length of the alfalfa roots. We are convinced that, when it is encountered by the roots, it practically determines their length; but when it is not actually encountered, its effect is problematical. If for any reason the depth of the water plane should be permanently lessened, as is the case when the higher land about a basin-shaped area is brought under irrigation, or irrigation water is increased, it would undoubtedly have a very serious effect upon the alfalfa, even to the killing of it if it should rise nearly or quite to the surface, especially if stagnant.

The water under the Whedbee field had a very strong flow; that under the field at Rocky Ford did not appear to have any; it was so far from the surface, however, that its effect would not be that of water filling up a basin-shaped area, and immersing the roots, in which case they would die out and rot.

EFFECT OF AGE UPON THE SIZE OF ROOTS.

There is no other point on which our observations are so at variance with one another as they are on this point. While we have not seen any young plant having a root so large as those mentioned from Weld county, we have seen many roots of six-year-old plants smaller than roots of other plants which we knew to be only nine months old. It can be stated in a very general way only, that one may expect larger roots among older plants than in a young stand. One of the chief causes of this is the fact that there is a natural process of thinning out, and the remaining plants have more room to grow and perhaps can avail themselves of the remains of the dead plants as a fertilizer.

DEATH RATE.

How fast this thinning out process takes place is difficut to answer. If there is any rule I have failed to observe it. In one instance I compared the casts of dead roots with the living ones in a piece of alfalfa five years from seeding, and the ratio of two to one seemed to hold good for the dead to the living plants. This is evidently open to question as to whether I could recognize the remains of plants that had been dead for several years, three or more; second, as to whether this ratio would hold for other soils as the death rate will vary under different conditions. The productiveness of this piece of alfalfa had not deteriorated very much and the variation in its tonnage may have been due to other causes than the dying out of a portion of the plants. This loss in number of plants is compensated for in part or wholly by the increased size attained by the remaining crowns. In the case of young plants or those crowded on account of the thickness of the stand twelve or fifteen stems may arise from a single crown, while crowns standing alone, i. e., occupying from six to eight or more square feet of surface, will throw out almost any number of shoots. I have counted as many as one hundred and sixty-one, and seen others two years old which had thrown out many more. For this reason I do not consider it of much importance whether the rate of dying is slow or rapid within reasonable limits and provided the

dying out is not confined to certain spots. There are two ways in which these plants perish: one is, that for some reason or other, the root just below the crown rots off, leaving the lower portion of the root perfect in every respect, so far as is evident to the naked eye. This is not apparently due to age or exhaustion of the vitality of the plant. The second manner in which they perish is due to age and other causes. If the stubble of the second year be examined by splitting it open down to the crown, there will be observed at the node above the crown a blackening of the tissue and also that it gradually extends downward into the root itself. It begins in this manner and continues until the whole center of the crown has been destroyed. The new shoots come out from the outside of the crown under the old growth and are in communication with the outer portion of the root and not with the interior vascular bundle. The central portion of the crown and interior of the root may be entirely destroyed to a depth of eighteen inches or more. This cavity serves as a nesting place for a variety of larvæ, but they have no direct part in causing it. The decay finally extends to such an extent that it involves the whole neck of the root and the plant perishes. This condition can be found in alfalfa of different ages. I have in mind one field, about seven years old, where the roots are large and nearly all of them are more or less affected in this way. I know of another six years old where the stand is extraordinarily thick and the roots small, and so few of them show this that one may say the roots are perfectly healthy. The former piece is on land which is rather low, with the water table about seven feet from the surface; the latter is on high land. The distance of the water table from the surface does not seem to be the sole cause of this dying, for I have observed it in plants growing in ground where the water table was probably not less than twelve feet from the surface, as this was its depth on a neighboring farm. This condition of the roots is illustrated in plates XV, XVI and XVII. The crown does not generally perish all at once, but is broken up into parts which die successively. The field from which the plants represented were taken yielded about three tons to the acre last year, and is, according to the best information I could obtain, over ten years old. The stand in this field is not much over one crown to the square foot, and the remains of many plants which have died within the past few years are still easily recognized.

The alfalfa root when destroyed below the crown does not throw out new buds and re-establish the plant, as many other plants do, and its ability to repair an injury to its

roots by throwing out adventitious roots seems to be very moderate. I have seen but few roots that have been eaten off by the pocket gopher or cut by the plow where it has calloused and thrown out roots which would be efficient in sustaining the plant if it had to depend upon them. I did not observe many with any roots produced in this way, but I have seen a few.

ALFALFA ROOTS CUT BY GOPHERS.

In a piece of bottom land near the Cache-a-la-Poudre river, I found a piece of alfalfa which was infested by these animals, and an examination of these roots showed that eighty per cent. of the plants had their roots eaten off, and this was doubtlessly the cause of the death of some of the plants, but they endured this severe root pruning to a surprising degree.

NODULES ON THE ROOTS.

Nodules appear on the roots in three forms: as warthy excressences mostly near the neck; as single nodules on small roots, and united into large colonies. The first form appears at shallow depths and whether these are identical with the others or not, they cease to appear on the roots at greater depths; while the third was found most abundant from three to five feet from the surface, and the second at all depths up to eleven and a half feet. There was a very great difference in the number of these on the roots at different localities though the plants seemed to be equally vigorous, and the proteids in the hay did not vary materially. They were found much more abundant on the plants grown in a garden soil, and also much nearer the surface than in the fields. The development of the colonies illustrated most vividly the influence of the alfalfa roots as mechanical agents for opening up the soil and admitting the air. I frequently found the passage left by the decayed root entirely filled by a colony or group of these nodules, whose axis agreed with the axis of the hole left by the root. Groups were almost invariably found occupying such passages or other cavities or clefts in the soil; while the single nodule was found scattered anywhere along the course of the root from the surface of the soil to the end of the root. Plate No. XI. shows some of the nodules as they occur near the extremity of the roots; these roots were about seven feet long. Plate No. XIV. shows large groups of them as found at a depth of from two and a half to five feet from the surface, and it also gives an idea of the size and character of the smaller roots of this plant. The largest

nodules were nearly spherical and were from an inch to an inch and a half in diameter. Some were irregularly hemispherical and nearly two inches long. Others resembled the antlers of a stag, some of the individual portions having a length of more than half an inch. Compared with the nodules on the vetch and red clovers, as they grow in our soils, the alfalfa is but poorly supplied with them; this is particularly true with some of the vetches, but the groups of these nodules are incomparably larger on the alfalfa. The branched groups occur on the vetches as well as on the alfalfa.

Some of these groups were submitted to a partial analysis. The samples were obtained from plants growing in a rich, dark loamy soil. The groups were found about three and one-half feet from the surface and rather more than this from the permanent water below. They were washed to remove the sand and dried between filter paper. The nodules contained 61.67 per cent. of moisture and the dried material 5.725 per cent. of nitrogen; while the bark of the roots contained 2.25 per cent. nitrogen. This included any nodules which chanced to be on the bark. No attempt was made to avoid them. The washing of both the roots and the nodules was quite unavoidable. There is no doubt that the composition of each was altered by the process; not enough, however,to materially detract from the significance of the results. The effect of washing the roots is described elsewhere.

RATIO OF THE ROOTS TO THE TOP.

The largest root which I dug up, was twelve feet six and one-half inches long, and the average diameter of all the roots measured (150) is one-half inch at the crown, and one-third of an inch, six and a half to seven inches below the crown, or at the average depth of plowing. The tops on the other hand at a period of their growth vary even more than the roots do, varying exceedingly as to the number of individual stems, and these vary even more in their thickness, leafiness and hight. In a plant of one season's growth, having but few stems and these slender, the root may be several times heavier than the top; and on the other hand the top of a favorably located plant may attain a weight of from four to seven and even more pounds, green weight, while the root will seldom exceed a pound. Our heaviest root weighed 418 grams, equal to about thirteen ounces, and was nine feet nine inches long Taking the average of all the plants which we have weighed, we find the ratio of roots to tops to be 1 : 1.3.

This at best can only be considered an approximation; first, for the reason stated above; second, because it is almost impossible to remove plants of the size of the ones with which we had to deal without loosing some leaves and stems, and still more difficult to get their original weight; for, do the best we could, evaporation from both roots and tops took place, though they did not show wilting to any extent. We weighed thirty-two plants, and the difficulty of the task may be appreciated in some measure when it is considered that the shortest plant handled, counting root and top, measured nine feet nine inches. The weight obtained for the roots is very nearly correct; while the weight of the tops is far too low, for the plants were already in seed when they were dug, and the loss by breakage and falling off of leaves was large, and to this is to be added the loss due to evaporation, which was unavoidable, as many of the plants which we weighed were secured twelve miles from the laboratory. There was no way of determining this loss, and we have no basis on which to estimate it. The closest approximation that we can make is on the following basis: first, assuming that the roots which we weighed were representative, we find their average weight to be 106.5 grams, green weight; second, we are justified by actual count in assuming that a good stand of five-year old alfalfa has about 140,000 plants to the acre; third, experiment indicates that the stubble is equal to about one-sixth of the green crop; fourth, five-year-old alfalfa referred to cut two and one-quarter tons of hay to the first cutting last year (1895), or 5,000 pounds, adding a loss of about twenty per cent. Seventy per cent. of the green crop is water, and thirty per cent. hay. All these data are based upon determinations made with as much accuracy as the subject will permit. Before proceeding with this calculation, it should be observed that the weight of the roots of the smaller plants exceeds the weight of the tops, sometimes being over three and one-fourth times as heavy. If the smaller ones are nearer the average, as is probably the case, the weight of the roots will exceed that of the tops of any single cutting.

Basing our calculations on these results, we have the two and one-half tons of hay, corresponding to 16,666 pounds of green crop; now adding one-sixth for stubble, gives us 19,443 pounds, or 9.72 tons. With 140,000 roots, each weighing 106.5 grams, we have, taking one pound as equal to 453.4 grams, which is near enough for our purpose, a total of 16.44 tons of roots, or a ratio of 1.69:1 for the roots to the total tops produced at this cutting, which

means that it is more than the average alfalfa plant on which the top equals or exceeds the root in weight.

STUBBLE.

Two efforts were made to determine the ratio of the stubble to the crop removed where the stubble includes the roots to the depth that they would be cut by the plow and the stems to the hight left by the mowing machine. In the first attempt the ratio of the stubble to the tops was determined by cutting off the plants at the depth of six or seven inches below the crown, weighing the whole plant, and then removing the top about as a mowing machine would cut it and weighing each. In this manner we would detect any loss if it occurred. The result of this method was that we found the ratio of 1:1.4 for the stubble to the green crop as cut for hay making. The second method was by plowing up a small piece of alfalfa five days after it had been cut, picking out the roots, and weighing them. The result of this was, allowing two and one-half tons for the total dry matter cut off of one acre at first cutting, that we obtained the ratio of 1:1.69. The agreement here is better than we expected, as the plants in the first case were all large, and, growing singly, and had larger than average crowns; while the second observation was made upon a field with a good stand in which the plants were crowded compared with the others. We are not far from the truth when we assume that the stubble turned under after the first cutting bears the ratio of 1:1.5 to the green crop removed, or is equal to two-thirds of the green alfalfa which has been cut, assuming that there has been no loss by falling off of leaves, breaking off of stems, etc., to which subject reference has already been made.

Three plats of 675 square feet each were plowed up at the end of April (April 28-29-30), and the stubble carefully picked out and weighed. On May 26, after having been kept for upwards of three weeks in the laboratory, the results obtained were, for Plat No. 1, 526,793 plants to the acre, ten years old, and 3.34 tons stubble. Plat No. 2, 333,514 plants to the acre, one year old, .81 tons. Plat No. 3, 70,238 plants to the acre, ten years old, 2.55 tons of stubble per acre. Omitting the one-year-old plat—no one would plow up a good stand of one-year-old alfalfa under ordinary circumstances—we have an average of 2.94 tons of air-dried substance per acre. On a subsequent page, under the manurial value of the stubble, it will be seen that we assume the amount to be 2.86 tons for plants five years old. This quantity was arrived at by accurately weighing a

small number of plants and estimating the total quantity. The agreement of the results by the two methods leaves nothing to be desired. The increase in the amount of stubble after the first year seems to be large, but it is not always so pronouced as appears from the above figures. I have seen one and five-year-old roots nearly equal in size, but the crowns of the plants five years old were much the larger.

COMPOSITION OF THE STUBBLE.

The stubble, of which an anslysis is herewith given, was obtained in the first effort to determine the ratio of stubble to the tops, already referred to. The plants were in seed at the time of cutting.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.
Air dried	5.16	4.24	.516	11.56	36.48	42.04	1.869
Water free	....	4.47	.518	12.16	38.19	45.00	1.945
Air dried	5.39	4.27	.577	11.15	35.50	43.05	1.788
Water free	....	4.51	.610	11.75	37.40	45.73	1.880

ASH CONSTITUENTS IN 1,000 POUNDS AIR-DRIED STUBBLE.

The following table gives the pounds of the various components of the ash in each one thousand pounds of air-dried stubble on the basis of 4.24 per cent. of ash:

Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Potash.	Soda.	Lime.	Magnesia.	Oxide of Iron.	Alumina.	Oxide of Manganese	Total.
1.104	4.155	1.261	1.156	7.762	2.307	8.831	2.681	.434	.289	.110	30.09

COMPOSITION OF THE ROOTS.

It was hoped that we would find time to submit the roots to a chemical investigation, but no other than the fodder analyses and analyses of the ashes of the bark, the inner portion of the root, and the whole root have been made. Trouble was met in preparing a sample of the roots. At first we endeavored to clean them by washing and wiping. This method proved inapplicable, for, as was noticed, the roots when moistened became sticky, absorbed water

greedily, and yielded a large portion to the wash water. Wiping with a wet cloth was also tried and finally rubbing with a brush was resorted to. This was the only practicable method, though it left much to be desired.

The green roots dried to a constant weight in the air gave 60.41 per cent. moisture and 39.59 per cent. of dry matter. The roots in sample No. 17 were from Weld county; No. 17-a Larimer county.

	Water.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.
No. 17, air dried	4.55	3.79	.71	10.81	25.13	54.98
Water free	....	3.97	.72	11.35	26.33	57.63
No. 17—a, air dried	5.04	3.69	1.07	10.07	24.18	55.95
Water free	....	3.88	1.15	10.66	25.46	58.85

The difficulty in preparing our samples suggested the following experiment: The roots were exhausted with hot water, the solution filtered, and evaporated to dryness. The residue, dried at 100 degrees C., amounted to 36.2 per cent. of the weight of sample No. 17 and to 45.3 per cent. in sample No. 17-a. A similar experiment with another sample showed that 44.23 per cent. of the total ash constituents were taken into solution. These facts show why washing the roots is inadmissable; also the extent to which the dead roots will give up their mineral as well as a portion of their organic matter to the soil waters, whose action is probably still greater than that of distilled water. Nothing was done towards determining the nature of the dissolved subtances except that their reducing power was determined by Fehling's solution. It corresponded to 12 per cent of sugar in the dried extract. This amount was not increased by boiling with sulphuric acid, with the usual precautions taken in the conversion of starch into sugar. The filtered extract seems not to have contained starch. The aqueous extract of the roots is acid toward litmus. It is possible that the sugar was produced by the action of the acid solution on the starch. I have expressed this reducing power in terms of sugar because it is convenient, not because it is known to be due to sugar. The taste of the roots in early spring is first sweet and afterwards bitter; the bitter taste is much more marked when the plant is more active. Cattle and hogs are fond of the roots, and I am informed, that horses also, readily acquire a liking for them.

ASH CONSTITUENTS IN 1,000 POUNDS OF AIR DRIED ROOTS.

	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Potash.	Soda.	Lime.	Magnesia.	Oxide of Iron.	Alumina.	Oxide of Manganese	Total
No. 17, washed	1.443	3 512	1.268	.295	8.879	.976	7.207	3.308	.453	533	.141	28.015
No. 17—2, not washed	1.267	4.554	2.266	.741	10.925	.944	8.540	4.245	.378	.325	.067	34.252
No. 17—a, washed..........	1.405	2.229	.706	.219	7.126	.396	7.430	1.921	.592	.418	.203	22.645
No. 17—a—2, not washed...	1.323	4.018	1.829	.471	10.201	1.831	4.777	2.300	.437	.406	.224	27.874

It is unfortunate that samples No. 17 and 17-2 are not portions of the same larger sample. They are roots obtained at the same place, but not at the same time. The same is true of No. 17-a, and 17-a-2. A comparison of the results indicates that the acids and the alkalies are removed from the roots in large quantities by washing them. This operation did not last more than ten or fifteen minutes at the longest and consisted in immersing them in water with gentle rubbing, until the dirt was loosened and then wiping them with a towel. The result in regard to lime is doubtful, as sample No. 17-a-2 contains less of this substance than the washed roots from the same place. Because of this doubt, a portion of sample No. 17-2, although it had lain in the laboratory about five months and the solubility of its ash constituents had possibly changed, was treated with tepid water, the extract evaporated to dryness and incinerated with the same precautions which had been taken in the preparation of ash from other samples. A partial analysis of this ash was made with the object of corroborating the results of the preceding analyses. The results are calculated on 1,000 pounds air-dried matter as before; on the basis of 1.6 per cent. ash dissolved out, 1,000 pounds yield to water sixteen pounds ash, containing 11.99 pounds fixed ash ingredients.

ASH OF AQUEOUS EXTRACT.

	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Potash.	Soda.	Lime.	Magnesia.	Oxide of Iron.	Alumina.	Manganese	Total.
No. 17—2, air dried..	.850	2.050	1.252	—*	5.166	.554	.660	1.270	.118	......	.070	12.0

* Not determined.

Showing that even a larger proportion of the phosphoric acid, sulphuric acid, and particularly of the potash, went into solution under these conditions than the preceding analyses indicate as probable.

MANURIAL VALUE OF THE STUBBLE.

Others have shown the fertilizing value of alfalfa hay, as grown in the east without fertilizers, to be $9 per ton, and when grown with fertilizers, $10.84 per ton.—Mass. State Rep. 1888, p. 165. Our farmers can not afford to turn under a crop of alfalfa preparatory to seeding to wheat or planting to potatoes, even if they get only from two to six dollars per ton for the hay as fodder, but they can afford, (and it would be good practice) to break up their alfalfa, say every six years, for at this age the average field has passed its maximum yield, and put in some other crop. To break up a field of alfalfa is a different task from breaking up one of clover or a timothy sod. In the case of clover it may be allowed to make a considerable growth in the spring before being turned under. This is not the case with alfalfa, for if the plant is allowed to stand late enough to make a growth sufficient to be of value as a green manure, or in fact any considerable growth, the toughness of the roots makes it difficult to break up; therefore, any attempt to estimate the manurial value of alfalfa in a field from a practical standpoint ought to be made on the basis of the stubble and roots taken while the plant is dormant. Our stubble was taken when the plant was active, and perhaps at the height of its activity, and our results are correct only for this period. We find the amount of stubble taken to a depth of about six and one-half inches to be 11,812 pounds per acre, and the moisture which this gives up in drying in the air to be 51.57 per cent. This moisture is undoubtedly rather low, and consequently, the air-dried material too high, due to the fact that our sample had lost water before it was possible for us to begin the determination. According to the preceding we obtain 5,720.8 pounds, or 2.86 tons air-dried matter per acre. Each ton of 2,000 pounds contains 8.31 pounds of phosphoric acid, 15.52 pounds of potash, and 36.37 pounds of nitrogen which, at fifteen cents per pound for the nitrogen, five and one-fourth cents per pound for the potash, and five cents per pound for the phosphoric acid, give the total value of the stubble at $19.28 per acre, $6.75 per ton for the stubble. The three substances mentioned are the ones to which it is customary to assign a money value. These are not the only elements which are returned or added to the soil by this manner of green manuring, nor have we in the preceding estimate the whole of these. We have stated that we included only the first six and one-half inches of the roots, the rest of th roots corresponding to 5.14 tons of air-dried matter per

acre, is left below the assumed depth of six and one-half inches.

MANURIAL VALUE OF THE ROOTS.

The manurial value of this portion is not equal pound for pound to the stubble, still it is by no means a negligible quantity. The nitrogen is equal to 14.98, practically 15 pounds per ton of 2,000 pounds; the phosphoric acid 4.45 pounds, and the potash 14.25 pounds; or stated differently, there is less than one-half as much nitrogen, one-half as much phosphoric acid, and about the same amount of potash in the roots as in the stubble, the first six inches of the roots being taken with it. On the other hand, while there is 2.86 tons of air-dried matter in the stubble, there is 5.14 tons in the rest of the roots, making them about equal to the stubble in the total nitrogen and phosphoric acid contained, and twice as rich in potash; or expressed in dollars and cents, the value of the roots below six and one-half inches, and to an average depth of ten feet, is phosphoric acid, $1.14; potash, $3.84, and nitrogen $11.60, a total of $16.58 against $19.32 for the stubble, making a total value per acre for the portion left after removing all the crop above ground of $35.90. In estimating this value all the other constituents of the ash and the organic matter have no value signed to them; whereas we know that the organic matter, particularly for our soils, has a comparatively high value, and the other ash constituents presumably in a more favorable condition for absorption by other plants than they are in the soil, can not be indifferent, though it is not usual to place any value upon them.

It may be questioned whether a large portion of the plant food stored in these roots does not lie so deep that it is beyond the reach of ordinary crops, such as potatoes and wheat. Whatever the answer of this question may be, it is a well attested fact, that the yield of wheat on alfalfa ground is often doubled and always greatly increased; and while the alfalfa is an exceptionally deep-rooting plant, no violence is done to observe facts in assuming that the roots of the wheat stimulated by the presence of plant food in certain channels left open by the decaying of the alfalfa roots, may penetrate to greater depths than they do when the food is disseminated evenly through the soil. The roots of the wheat plant, however, have been observed to penetrate to the depth of seven feet—Schubart cited by Johnson, "How Crops Grow," page 264—which is as deep as a large percentage of the alfalfa roots penetrate into our soils.

It is necessary in this connection to distinguish between the roots and the soil in which they have grown, for while the roots contain, as we have seen, a large amount of plant food, particularly nitrogen, it does not follow that the soil itself contains as much of this element as it did before the alfalfa was grown in it ; in other words, if the alfalfa roots were removed, the soil might be poorer in nitrogen as it certainly would be in other elements of plant food. If the amount of nitrates in cropped soils be taken as the measure of available nitrogen in a soil, alfalfa exhausts a soil faster than many other crops. Aikman, in "Manures and Manuring," page 157, quotes the amount of nitrates found in cropped soils per acre (Rothamsted soils), from which it appears that there is the following amount of nitrogen as nitrates in each acre of soil taken to the depth of nine feet: In soil cropped to white clover, 102.8 pounds; to vetches, 54.6 pounds; to wheat, after fallow, 18.4 pounds, and to alfalfa, 17.0 pounds. It is further shown for the soil cropped to alfalfa, that while the first nine inches of soil contains 8.9 pounds per acre, the last nine inches taken, that is, from eight feet three inches to nine feet, contain only 0.4 pounds; while in the soil cropped to white clover there is at the same depth (eight feet three inches to nine feet), 10.0 pounds, showing how great a draft the alfalfa had made upon this form of nitrogen in the soil.

There is a suggestive fact shown by the figures of the table as quoted, i. e., the first nine inches of soil contain after vetches a trifle less than one-fifth of the total taken to the depth of nine feet, and more than one-half of the total after alfalfa. The dimunition of the nitrogen after the alfalfa is almost continuous to the depth of eight feet three inches; where, as given above, the amount of nitric nitrogen is only 0.4 pounds per acre; while in the other cases, the dimunition reaches its maximum at a depth of between two and three feet, from which point on the nitric nitrogen increases somewhat, being present in the largest quantity after white clover at a depth of four and one-half to six feet.

The figures given in this connection show more clearly than any others with what avidity and also the depth to which alfalfa feeds. I do not think that the movement of the nitric nitrogen (nitrates) in the soil can operate to produce this marked result in the case of the alfalfa, but that the nitrogen is appropriated by the plant.

LEAVES AND STEMS AS A TOP DRESSING.

It has been repeatedly stated that the mechanical loss in making alfalfa hay is very considerable, and while I have

no figures established by experiment—the reason has been given elsewhere—I estimate the minimum to be between fifteen and twenty per cent. of the total dry matter, including all the leaves that fall during the growth of the plant and the making of the hay. I believe twenty per cent. of the dry matter to be a reasonable estimate. The amount of matter added to the soil in the form of a top dressing on this basis of loss is more considerable than at first appears. The actual amount ranges from .95 ton for a 3-ton yield of hay to one ton for a 5-ton yield. It is not only twenty per cent. of the total dry matter, it is about one ton of the richest portion of the crop, equivalent to the addition of 70.4 pounds of nitrogen and 168.8 pounds of ashes. Some of the nitrogen may be lost, but the whole of the ashes is available. The table quoted by Prof. Aikman shows that the first nine inches of the cropped soils are rich in nitric nitrogen, and in the case of the alfalfa they contained more than one-half of the total found to the depth of nine feet, 8.9 pounds out of a total of 17.0 pounds.

These facts may be more directly related than at first appears. The ashes contain seven pounds of phosphoric acid and 28.6 pounds of potash, which have been brought up from below. A portion of this is, doubtlessly, taken up by the plant and utilized in making the next year's crop; but there is a remainder each year which accumulates to the enrichment of the surface portion of the soil. The accumulation of nitrogen is probably less in Colorado than it would be were our conditions more favorable to the formation of humus in the soil. There is no series of analyses showing how great the changes in the surface soil are in respect to humus, nitrogen, or ash constituents; we have only the general results as measured by the increase in wheat produced, and this only in general terms. I have presented the composition of the plant and its parts; the amount of plant debris added year by year; the stubble added to the soil at the end of one, five, and ten years; also the amount of roots not included with the stubble; and I have also intimated another source of addition to the soil during a part of the life of an alfalfa field, i. e., by the perishing of the inner portion of the roots. The composition of the plant debris has been given and the following tables contain the analyses of stubble and roots and the fixed ash constituents for each thousand pounds of air-dried material :—

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.	Amide Nitrogen.
Stubble	5.16	4.24	.546	11.56	36.48	42.01	1.849	.202
Stubble	5.39	4.27	.577	11.15	35.50	43.04	1.788	....
Roots, Weld County	4.64	3.72	.72	10.99	25.30	54.63	1.840	.281
" Weld County	4.46	3.86	.66	10.73	24.96	55.33	1.794	....
" Larimer County	5.03	3.69	1.04	9.96	24 15	56.13	1.590	.257
" Larimer County	5.04	3.69	1.13	10.17	24.21	55.76	1.630	.....
" outside portion	4.38	5.21	2.06	14.08	21.75	52.52	2.253	......
" inside portion	3.77	3.50	2.81	7.70	29.19	53.03	1.231	......

ASH CONSTITUENTS IN 1,000 POUNDS AIR DRIED SUBSTANCE.

	Silica.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Lime.	Magnesia.	Iron Oxide	Alumina.	Manganese Oxide.	Potash.	Soda.	Total.	Nitrogen.
Stubble	1.104	4.155	1.261	1.156	8.831	2.681	.434	.289	.110	7.762	2.307	30.090	18.186
Roots, Weld Co	1.267	4.554	2.266	.741	8.540	4.245	.378	.325	.067	10.925	.944	34.252	18.400
" " washed.	1.443	3.512	1.268	.295	7.207	3.308	.453	.533	.141	8.879	.976	28.015	17.94
" Larimer Co	1.323	4.048	1.829	.471	4.777	2.300	.437	.406	.224	10.201	1,831	27.847	16.30
" " washed.	1.405	2.229	.706	.219	7.430	1.921	.592	.418	.203	7.126	.396	22.645	......
" bark	3.075	4.768	3.206	1.086	7.298	3.337	.728	.824	136	13.277	2.998	40.733	22.53
" bark	2 386	4.285	3.190	1.218	8.225	5.558	.507	.738	.205	11.469	1.118	38.899	......
" inside	.403	3.987	1.776	.434	5.060	4.197	.242	.053	.078	8.204	2.574	27.008	12.31
" inside	.361	5.389	1.642	.477	7.070	4.085	.174	.079	.098	6.282	.815	26.472	......

The work on the soils from our standpoint is quite unsatisfactory, but either someone else or ourselves may be able to make a systematic study of this subject which is of some importance as well as of interest to the West.

The soil in which the Weld county samples were growing was sampled to the depth of eleven and one-half feet in three parts, corresponding to the large variations in the character of the soil; at the same time a sample of soil was taken a few feet distant from a field planted to corn, but owing to lack of water it was practically fallow at the time. The corn plants had made no growth during the season; subsequently a fifth sample was taken of the blown soil which gathers about the large crowns of alfalfa containing a great many leaves and plant refuse. This enables us to present the composition of the plant, the root, the soil accumulation about its crown, the soil proper, the subsoil in two sections, and that of a sample of the soil not in alfalfa. The alfalfa was six years old. The plants were very large, some of the stems being over five and one-quarter feet high, and the largest of the roots one and one-half inches in diameter, with abnormal roots, i. e., such as had short tap roots two to three feet long attaining a diameter of two and

seven-eighth inches. The soil is a very fine clayey loam, almost black in color and 21½ inches deep. It had never been broken by the plow to any depth and was so compact that we were compelled to use a pick in working a part of it. This is succeeded by six feet of marly clay and fine sand, the upper four to six inches of which was a white marl and the next three and a half feet fine clayey sand. The sample from the cornfield corresponds to the 21½ inches of black soil. For fodder analysis of plant see page 31, first cutting, analysis No. 12.

The total fixed ash constituents removed by 1,000 pounds of hay, on a basis of 8.87 per cent. moisture and 9.94 per cent. crude ash, is 75.32 pounds, distributed as follows:—

Silicia	1.49
Phosphoric acid	4.43
Sulphuric "	5.59
Chlorine	7.92
Lime	23.65
Magnesia	5.89
Oxide of iron	.40
Alumina	.25
Oxide of manganese	.19
Potash	23.69
Soda	1.82
	75.32
Nitrogen	22.31

ANALYSES OF THE ASHES.

Plants.	Per cent.
Sand	1.765
Silicic acid	1.513
Phosphoric acid	4.459
Sulphuric "	5.636
Chlorine	6.776
Calcic oxide	23.905
Magnesic oxide	5.951
Ferric "	.397
Aluminic "	.253
Manganic " (brown)	.188
Potash	23.934
Soda	1.840
Carbonic acid	25.151
	101.768
Less O equivalent to Cl	1.523
	100.245

Roots.

	Per cent.
Sand	2.380
Silicic acid	2.875
Phosphoric acid	10.270
Sulphuric "	5.093
Chlorine	1.322
Calcic oxide	19.008
Magnesic oxide	9.492
Ferric "	.844
Aluminic "	.729
Manganic " (brown)	.149
Potash	24.443
Soda	2.110
Carbonic acid	21.742
	100.457
Less O equivalent to Cl	.299
	100.158

ANALYSES OF THE SOIL.*

	Soil Blown about Roots.	Black Soil to Depth of 21½ Inches.	Marly Soil fr'm 1 Ft. 9 In. to 7 Ft. 9½ In.	Fine Clay and Sand from 7 Ft. 9½ In. to 11 Ft. 3½ In.	Soil from Corn Field, Corresponding to Black Soil.
Insoluble Matter	78.472	66.700	55.032	68.145	63.258
Soluble Silicic Acid	9.174	15.110	12.921	10.082	16.086
Potassic Oxide	.327	.610	.531	.416	.409
Sodic Oxide	.093	.235	.368	.250	.152
Calcic Oxide	.562	.570	9.182	4.775	.755
Magnesic Oxide	.551	.852	2.016	1.185	1.251
Manganic Oxide (brown)	......	......	......	......	.....
Ferric and Aluminic Oxides	5.835	8.931	7.937	7.005	9.780
Phosphoric Acid	.143	.186	.195	.132	.148
Sulphuric Acid	.065	.070	.102	.057	Trace.
Chlorine	.004	.005	.007	.003	.003
Carbonic Acid	Trace.	.017	7.842	3.606	.293
Moisture	1.400	1.797	1.629	1.431	2.052
Volatile and Organic Matter	not det.	3.338	2.050	3.291	5.534
Total	......	98.421	99.812	100.378	99.721
Nitrogen	.085	.076	.035	.025	.062
Humus	......	.400	......	.200	......

* Analyses by Mr. Chas. Ryan.

In the mechanical analyses of the soils we followed as closely as we could the method of Osborne, but we had no sieve corresponding to .1 mm., and but one portion is made between .25 mm. and silt. There is a large quantity of

calcic carbonate and silicate, particularly in sample B., which is distributed between the three last portions. Imperfect as the analyses are, they serve the purpose for which they are used.

	.5 mm.	.25 mm.	.10 mm. and Sand.	Silt.	Clay.	Dust.
Soil A	6.888	8.820	72.450	3.433	.410	7.999
Soil B	4.416	11.130	73.745	3.213	2.247	5.249
Soil C	6.011	15.200	68.650	5.090	.120	.493

Analyses by Mr. Chas. Ryan.

The physical condition of this soil is excellent when it has been mellowed by tillage, but is compact when it retains the natural firmness acquired by its long-settling and the firming of its particles. The degree of flocculation is small. The particles are fine and puddle easily. The amount of alumina and iron—we may say alumina, for their is very little ferric oxide in the soils—together with the soluble silica convey a fair idea of the exceedingly fine state of division prevailing in them. The amounts of potash, phosphoric acid, and nitrogen are abundant. We used hydrochloric acid sp. gr. 1.115 in extracting the soil, and with the large amount of calcic carbonate present in some of the samples, the action of the solvent was propably not excessive; so that, after entertaining every misgiving as to the value of the results obtained by a chemical analysis, we may accept the amount of plant food taken into solution as representing approximately the amount available in this soil. Here it should be noted that no attempt was made to determine the extent of this soil, but as it is common to find it, we assume that it is not an exceptional soil, though it is by no means so common that it can fairly be claimed to represent the general soil of the county.

In estimating the amount of ash ingredients removed by the crop of alfalfa from this soil, the basis of 9,000 pounds of hay per acre may be assumed as a convenient estimate. The amount of ash ingredients removed for each 1,000 pounds of hay has been given for this particular case as 75.32 pounds, or for the 9,000 pounds—four and one-half tons—677.88 pounds distributed as follows :

	Pounds.
Silicic acid	13.41
Phosphoric acid	39.87
Sulphuric acid	50.31
Chlorine	71.28
Lime	212.85
Magnesia	53.01
Oxide of iron	3.60
Alumina	2.25
Brown oxide of manganese	1.71
Potash	213.21
Soda	16.38
	677.88

The nitrogen in the hay amounts to 200.79 pounds. The amount of plant food in the soil, however, is so large that it is scarcely possible but that a very large excess over that required by the crop was obtainable at all times throughout the season. The total plant food present in the soil penetrated by the roots in this case is so large that it seems to have no object in trying to express the quantity in figures. The quantity of phosphoric acid present in one acre of this soil and its subsoils taken to the depth of eleven and one-quarter feet is approximately thirty-four and one-quarter tons, and about three times as much potash, or one hundred and two tons. It would seem probable that,under these conditions, the plant would contain as large a quantity of ash ingredients as it could take up,but the average ash content of alfalfa hay,including all cuttings and varieties of alfalfa grown in Europe and different parts of this country, is 7.44 per cent., or nearly as great as the average of the samples collected by ourselves, including this particular one, 9.08 per cent., for the first cutting and rather higher for the second and third cuttings. Our averages are something higher than that given by Mayer and others. This difference is reduced a little when the lower water content of our hay is taken into consideration; but there still remains an excess over the average ash content. This may correspond to the amount which is taken from our soils in excess of the normal amount due to an excessive supply. It is to be remembered that the alfalfa in our case is practically growing in a virgin soil, even if the upper soil has previously been sown to wheat, for the wheat roots, whatever depth they may attain in loose open soils,

can not attain great depths in our prairie soils unless they have been opened by some preparatory crop or process. It is probable that the amount of ash constituents taken up by our alfalfa does not exceed ten, or at most, fifteen pounds per hundred, indicating an amount necessary for the perfect maturing of this plant, which only a rich soil can furnish or a most vigorous root system collect.

We have no other series of soil samples so complete with the hay produced upon the same, but we have one sample from Rocky Ford, Otero county. The hay is a sample of the third cutting; the yield for the year, three cuttings, was five tons. An analysis of the hay gave the following: water, 6.06 per cent.; ash, 9.87 per cent.; fat, 1.29 per cent.; crude fiber, 32.69 per cent.; protein, 13.69 per cent., and nitrogen free extract, 36.40 per cent. The fixed ash constituents amounted to 73.788 pounds for each 1,000 pounds of hay, as follows: silicic acid, .828 pound; phosphoric acid, 3.258 pounds; sulphuric acid, 5.280 pounds; chlorine, 7.444 pounds; lime, 23.684 pounds; magnesia, 3.033 pounds; oxide of iron and alumina, .662 pound; brown oxide of manganese, .153 pound; potash, 27.197 pounds; soda, 1.976 pounds; or the total removed from the soil by the five-ton crop, supposing it all to have been as rich in ash as the third cutting was 737.88 pounds.

The Weld county sample, already given, shows 677.88 pounds ash constituents, based upon the first cutting and a yield of four and one-half tons. If we assume a five-ton yield, to make them more easily comparable, we have 737.88 pounds of ash in Otero county, third cutting, as against 753.2 pounds in Weld county, first cutting; a difference of about 15 pounds, only three pounds for each ton, or only about two per cent. of the total ash constituents considered. This difference is less than that usually found between two samples cut at different times from the same plat.

We fortunately have an analysis of the Otero county soil, also made by Mr. Ryan. The point at which this sample of soil was taken is not, as in the case of the Weld county sample, the one at which the hay sample was gathered; but, after examining the soil, I am satisfied that, owing to its uniformity, no error is introduced by the fact that the sample is not the identical soil in which the plants had grown and there can be no doubt but that its value is as great as that of any chemical analysis which might be made of this soil.

ANALYSIS OF SOIL FROM OTERO COUNTY.

	Per cent.
Insoluble	77.72
Potash	.25
Soda	.11
Lime	1.55
Magnesia	.11
Ferric oxide	2.93
Alumina	4.70
Phosphoric acid	.90
Sulphuric acid	.45
Chlorine	.04
Carbonic acid	1.01
Moisture, at 110 degrees	1.66
Loss by ignition	3.70
	100.45

This sample does not represent the soil to a greater depth than four and a half feet; while the preceding ones, together, represent the Weld county soil to a depth of eleven and a quarter feet. The twenty-one inches of Weld county soil contain 11,208 pounds of phosphoric acid to the acre; while the Otero county soil, calculated to the same depth, contains 55,125 pounds of this acid, or nearly five times as much. The ratio of the potash in the two soils is markedly in favor of the Weld county soil, it containing in the first twenty-one inches 37,362.5 pounds; while the Otero county sample contains 15,312.5 pounds. The amounts of these substances removed by the respective crops bear no such relation to each other as the total amounts of them bear to one another. The amount of phosphoric acid removed by one thousand pounds of hay from the Weld county soil is 4.43 pounds; while the amount removed from the Otero county soil, by an equal weight of hay, was 3.58 pounds. With a total quantity of phosphoric acid, five times greater than that present in the Weld county soil, the plants have taken up a little more than three-quarters as much of it. The potash removed by a thousand pounds of hay from the Weld county soil was found to be 23.69 pounds; while from the Otero county soil, with less than one-half as much total potash, this weight of hay removed 27.197 pounds. The magnesia, it was hoped, might give a clue as to the amount of food brought up from the lower portion of the soil, as we have the ground water quite heavily laden with salts of this base; but an examination of the results obtained failed to show any such relation as might even be suggestive that these solutions had anything whatever to

do with the nourishment of the plants. The Weld county sample contains for each 1,000 pounds of hay, 5.89 pounds magnesia; the Otero county sample only 3.033 pounds. The Weld county soil contains about one per cent. of magnesia and the Otero county soil only a little over 0.1 per cent., but in the latter case the roots penetrate the ground waters, which are rich in magnesia salts, as the following table illustrates:

COMPOSITION OF GROUND WATER.

Calcic sulphate	155.650
Sodic "	341.771
Magnesic "	51.880
" chloride	29.027
" carbonate	16.026
Insoluble	2.412
	596.766

The total solids per gallon was 596.766 grains.

Examination failed to reveal the presence of phosphoric acid or potash, despite the large amount of the former in the upper portion of the soil and a fair abundance of the latter. The condition of the roots was good, although they were very different from those in Weld county, and also from others in Larimer county, which had penetrated into flowing water near the level of the Cache-a-la-Poudre river. These roots were neither "rotten" nor dead, but living, and were doubtlessly discharging their functions. I, of course, cannot tell to what extent their action had been modified; but it is evident that, so far as the magnesia is concerned, they had not taken enough of it into the plant system to make its amount equal to that taken from the Weld county soil. We are in this case debarred from trying to explain the difference in the amount of magnesia appropriated by the plant by the less amount of lime in the Weld county soil, for the fact is, that the Weld county soil is very much the richer of the two in lime; and moreover, the amount of lime in 1,000 pounds of the samples is almost identical, i. e., 23.65 pounds in the Weld county sample and 23.69 pounds in the Otero county sample; nor yet is it probable that the potash taken up influenced the amount of magnesia so far as the analyses indicate; the Weld county sample has 23.69 pounds and the Otero county sample 27.20 pounds of potash for each 1,000 pounds of hay. There is here an excess of potash in favor of the Otero county sample, about equal to the deficit of magnesia, which fact alone would have but little signifi-

cance; but it acquires some weight when it is observed that the sum of the lime and potash, including magnesia with the former and soda with the latter, is constant within comparatively narrow limits, i. e., they are equal to from 55.5 to 59 or 60 per cent. of the total ash constituents of the plant above ground; but this is not true of the roots to the same extent, nor of the leaves and stems taken separately. The magnesia in the roots is as a rule higher than in other parts of the plant; while the nearly constant sum of these four constituents—the two, potash and soda, rising as the lime and magnesia fall, or contrariwise—might be interpreted as indicating an intimate relation between their relative quantities and a partial interchange of functions. The varying relation of their quantities in the ash of the leaves, stems, and roots, obscures this to such an extent that we can say nothing definite about it; and for this reason we believe it improbable that the four per cent. more of potash in the Otero county sample has any direct bearing upon the lower percentage of magnesia in it than in the Weld county sample. There was an abundance of magnesic salts presented to the absorptive action of the roots of the Otero county plants, but the fact is the salts were not taken up, nor is the amount of soda present in this sample apparently influenced by the soda salts present in the soil waters, for in the Weld county hay we find 1.82 pounds of soda for each 1,000 pounds of hay, and in the Otero county 1.98 pounds. In other samples, grown in alkali soils, we have from two to three times as much soda present as we find in either of these samples. We have omitted some essential condition or we are justified in concluding that the supply of plant foods is so excessive in both of these soils that the plants in each case have taken up as much of the various ash constituents as they could appropriate, or that the available supply in the two soils was about the same and that the ground waters exercised no decided influence upon the character or amounts of these constituents taken up. Such a conclusion, if established, would be in harmony with the suggestion already made, that the alfalfa plant may feed at greater depths, but it does not necessarily do so, and that it can dispense with its long tap root and still flourish.

The ground water met with in the above instance is rather a "bitter water" than an alkaline water, even though there is a large portion of sodic sulphate present. Combining the bases with the acids in the following order: sodium, calcium, magnesium, we have the following percentage composition of the thoroughly dry residue:—

	Per cent.
Silicic acid	0.5
Sodic sulphate	57.3
Calcic sulphate	26.0
Magnesic sulphate	8.7
Magnesic chloride	4.8
Magnesic carbonate	2.7
	100.0

The composition of the water accounts for its nauseating, bitter taste. It was clear and almost sparkling. We give the following analysis of a seepage water collected late in the season from a newly opened drain running through an alkalized and somewhat marshy swale. The larger quantity of salts held in solution and their difference in character, distinguish the ground water from the seepage water. The magnesic salts in the seepage water have evidently been taken up from the soil. The water used for irrigating was practically snow water. I have no analyses of the Arkansas river water at my command. I have no doubt but that it is quite as different from the ground water as the seepage water is, and resembles the latter much more than it does the former.

Ground Water.

Total grs. per gal.	596.766
Sodic sulphate	341.771
Calcic "	155.650
Magnesic sulphate	51.880
" chloride	29.027
" carbonate	16.026
Insoluble	2.412
	596.766
Total magnesic salts	96.933

Seepage Water.

Total grs. per gal.	97.85
Sodic sulphate	54.38
Calcic "	29.47
Magnesic chloride	7.50
" carbonate	5.27
Insoluble	1.23
	97.85
Total magnesic salts	12.77

This seepage water is from Larimer county, and the different conditions of soil and the different waters used for irrigation influence the character of the salts taken into solution or left by evaporation and consequent concentration. The writer does not know the history of the land from which this drain water was taken; but there is no doubt that it is a seepage water which had collected in the lower portions of the farms and was drawn off by the laying of this drain. The water used for irrigating was taken from the Cache-a-la-Poudre river. The water supply for the city of Fort Collins is taken from the same source, and as delivered for domestic use contains in the month of February, when the water is low, rather less than ten grains of solid matter to the gallon. This gives us a general, though somewhat indefinite, idea of the amount of salts due to concentration and solution from the soil.

The Arkansas river water may contain more solids when taken out for irrigating purposes, but there is little doubt that the magnesic salts, in both cases, are taken into solution as the result of chemical changes between the salts of the soil and those taken into solution by the water. The ground water is not so different from the seepage water, but that it may be considered as a product of the concentration of seepage waters. This is not the place to discuss the manner in which this concentration has been effected. We have intimated an answer to the most patent inquiry, i. e., whence the magnesic salts contained in both the samples, the ground as well as the seepage waters, especially as the irrigating water used is river water, supplied by melting snows and flowing for the greater part of its course over gneissic or granitic rocks. This is more literally true of irrigation water used in parts of this county (Larimer) than it is of that used in Otero county, which is farther removed from the mountains. The analyses of drain waters taken in European soils are not closely comparable with our seepage waters, for these soils have been washed out and ours, in this semi-arid climate, have not been; still even the European drain waters show a relatively large amount of magnesic carbonate present in them ranging from one-third to one-twelfth of the total lime salts.

This subject may form the basis of some future work by the department, though the subject has already been approached in Bulletin No. 9, of this Station.

The relation of soil water to the salts taken up by plants is apparently not the same as that sustained by solutions in water culture. Our alfalfa roots have not taken it up from this depth. We have given analyses of the soils

and of the ground water and we place the analyses of the ashes of the hays side by side for easier comparison.

	Weld Co. Per cent.	Otero Co. Per cent.
Carbon	.000	.020
Sand	1.765	1.261
Silica	1.513	.858
Phosphoric acid	4.459	3.714
Sulphuric acid	5.636	5.477
Chlorine	6.776	7.721
Lime	23.905	24.524
Magnesia	5.951	3.141
Ferric oxide	.397	.683
Aluminic oxide	.253	
Brown oxide of manganese	.188	.156
Potash	23.934	28.209
Soda	1.840	2.055
Carbonic acid	25.151	24.053
	101.768	101.777
Less O equivalent to Cl	1.523	1.739
	100.245	100.038

The results of our study and observations as to the effect of alfalfa growing upon our soils are briefly stated as follows:

The biological relations of the soil are probably materially improved by the maintenance of a more uniform tempature during the heat of the summer days, by the maintenance of greater uniformity of moisture, and by a supply of organic matter. The shade and moisture furnished or conserved by a growth of alfalfa must evidently exert a pronounced influence upon the soil conditions, and not only improve the biological conditions, but also favor chemical changes, particularly humification processes.

There is added yearly to the surface portions of the soil a large amount of mineral matter by the falling portions of the plant, leaves, stems, etc., which, with the shade and moisture furnished to facilitate their decay, amounts to an excellent top dressing. The slowness with which straw, leaves, etc., decay in our soils with the ordinary supply of moisture, almost prevents such material from serving any good purpose as manure or as a means of forming humus in the soil, and anything which facilitates this process is of a decided advantage; for the physical condition of our soils, while good, can be improved in this direction.

There is no doubt but that the return of the plant food appropriated and deposited in the leaves and stems which fall upon the surface may be slower than it would be under humid atmospheric conditions; still it goes forward somewhat faster under the influence of the shade and conserved moisture of a thick growth of alfalfa than it would otherwise do, and the surface soil must have a very considerable amount of mineral ash constituents added to it in the course of six or more years. Some may be flooded off by irrigating, some may be blown away, and a large amount may be taken up in the production of subsequent alfalfa crops ; still there can scarcely fail to be a large residual amount of available plant food collected in the first few inches of the soil. I am satisfied that this factor in the improvement of the soil has not received the consideration it deserves. It is one of those factors, however, that is just as potent without as with recognition, for the leaves fall and can not be prevented. I have elsewhere, in speaking of the loss in hay making, stated that from fifteen to twenty per cent. is about the minimum, and taking it at twenty per cent., and this is scarcely too high, we have a top dressing of leaves weighing one ton for every five tons of hay taken off, and as this amount of hay may be cut from an acre in one season, though it is too high for the average, we may calculate the annual dressing of leaves, etc., at one ton per acre. The total ash in this is 269 pounds, taking the ash of the leaves at 13.45 per cent., which is the average of four determinations. The 269 pounds of ash contain 11.83 pounds of phosphoric acid and 49.22 pounds of potash, equal to 25.79 pounds bone phosphate and 77.73 pounds chemically pure muriate of potash. To these are, of course, to be added the ash ingredients, for instance, the lime equal to 76 pounds caustic lime and upwards of 30 pounds sulphuric acid (SO_3); also nitrogen, equal to 74 pounds. It would require 449 pounds of sodic nitrate to furnish this amount of nitrogen. The yearly top dressing from this source alone is equal to 25.79 pounds pure calcic phosphate (bone phosphate), 77.73 pounds pure muriate of potash, and nitrogen equal to 449 pounds pure sodic nitrate. We take into consideration the facts that the organic nitrogen is not worth as much as the nitric nitrogen ; that some of these constituents may be lost ; also that much of it will be used by the growing plants, and still, as I have before said, the residual manurial elements must be large.

The value of the stubble and roots in the soil has been shown to be about $35 per acre, for the nitrogen

phoric acid, and potash, attributing neither influence nor value to the other fertilizing elements, which is justifiable only on the ground that we have neither a commercial nor a conventional measure of value for them, particularly the easily decomposable organic matter which has more value in our soils than it would have in many others. The humus in our soils is not high—in the samples given 0.4 and 0.2 per cent. respectively—and they produce good crops, but the addition of this form of organic matter would better their mechanical condition and very probably their productiveness. As the increase of humus in these prairie soils is not easy, I believe that we ought to value highly the easily decaying alfalfa roots.

There is still another manner in which the growing of this plant benefits our lands for cultivation: it opens up channels through compact substrata to a considerable depth, allowing the entrance of water and air. The writer unfortunately does not know whether hardpan streaks are frequently met with or not, but, so far as his observation goes, they are not; compact layers are met with, but the alfalfa roots have penetrated all of these which he has examined with this point in view. The size and length of the average roots in this country are not at all consonant with popular estimate, nor yet with the descriptions given of them as found elsewhere; but their power to penetrate tough clays and hard streaks is great enough to make them most excellent subsoilers. The soil of a field which has been to alfalfa has practically been deepened for a subsequent sowing to wheat. I have not seen, nor do I know of any observations having been made upon the root development of wheat in our prairie soils or as to the depth to which they penetrate in virgin soil, where there is a very fine, compact, and tough substratum, the result of the settling and compacting of ages To plant such a soil to alfalfa is to perforate this compact subsoil with numerous channels for the passage of water and air and for the entrance of other roots when those of the alfalfa have rotted. The work done by the alfalfa roots in accomplishing this is very great, but this work is to the benefit of the soil, the advantage of the succeeding crops, and to the profit of the owner, being the cheapest labor as well as the best directed and most efficient of any which he can employ.

A very common practice among our ranchmen ought to be particularly mentioned here, though it is only incidental to the object of this bulletin and is self-evident, needing only that attention should be directed to it. The great benefit accruing to worn out wheat soils by being sown to

alfalfa is so marked that it is a matter assumed to be a fundamental fact of our Colorado farming. Alfalfa hay does not, at present prices, bear transportation, except it can be converted into some more markatable form; and this has been the case for years. Until recently the fattening of steers was profitable, and, consequently, a favorite manner of marketing alfalfa hay. The crop was fed in the field, the animals pasturing and feeding on the ground upon which the crop grew; this was practically equal to returning the crop to the soil from which it was taken. Of course, the practice is not without some drawbacks; still the crowns were not tramped to death and the voidings of the animals were equivalent to manuring the surface soil with the crop grown upon it. There is no question but that this is not an economical way of treating the manure; but, in spite of the losses, a large amount of the manurial elements of the crop were returned to the soil. This does not hold for sheep feeding, and unless our farmers pay more attention to the manure of the sheep-fold, some of the beneficent effects of alfalfa growing observed in the past will be wanting in the future. The care of this manure is an important question to the people of this community. The alfalfa is a heavy feeder and lays a tax upon the soil for every benefit it bestows. The apparently wasteful methods of the past have tended to gain all the advantages from growing this plant and to obviate any disadvantages. If the same good results are to be maintained under a changing system of feeding, care must be exercised, and the manurial equivalent of the crop must be returned to the soil.

APPENDIX.

In the preceding pages I have given the general results of our study of the development of the alfalfa plant, mostly in numbers based upon hay, because this is the condition with which the average reader is most familiar, and the details of the preparation of samples, so far as there is any need of their being given at all, have been given ; but there are some details deserving of mention and yet of less interest to the public than the general discussion. Some of these may find place here, together with the tabulated results based upon thoroughly dry material.

PREPARATION OF THE SAMPLES.

The samples of hay were prepared with the utmost care in order that the samples should represent the best grade of hay possible to be prepared from plants in that stage of development. They were protected from undue exposure to sun, wind and rain ; in fact, they were cured in muslin sacks and brought into the laboratory whenever there was any rain and during the night; so that they were not exposed to the effects of dew or moisture other than the hygroscopic changes in the atmosphere itself. We found that the protection from blowing sand and from loss of leaves due to the wind and drying of the plants was absolutely necessary in order to have our samples represent the plant as it actually was at the time of cutting. The sand found in the analyses of plant ashes is partly accounted for, in our cases, by its being blown upon the plant during the preparation of the sample ; some of it, however, is lodged in the axils of the leaves and stems, or even driven into their tissues by the winds. This method was very tedious, requiring as many as ten days, even in this climate, to get some samples to a constant weight. A few experiments were made to determine the

effect, if there was any, of drying the sample at 100 degrees C. and then exposing the dried hay to the air until it had saturated itself with moisture under the usual atmospheric conditions. We found this much more convenient and without effect upon the analytical results. The samples, however they might have been prepared, had to be sealed, and every precaution taken to prevent their absorbing more moisture, which in the closed bottle, they did not so readily give up.

PREPARATION OF THE ASH.

The method pursued in preparing the ash was, to heat a large platinum dish over the flame of a small Argand burner so strongly that the bottom, the room being partially darkened, began to show a dull redness over an area from one to one and a half inches in diameter; the weighed sample was introduced in separate portions until the charred mass filled the dish to rather more than two-thirds full, when it was allowed to continue heating until the volatile matter was nearly or quite expelled; the bulky mass was then transferred to a porcelain casserole and allowed to burn of its own accord so long as it would. The mass was stirred frequently and new portions of the sample were treated in like manner until the whole of it was brought into the casserole. When it had burned out and cooled sufficiently the still highly carbonaceous ash was extracted with water and washed so long as the wash water showed the presence of chlorine. The insoluble portion free from chlorine was then burned to whiteness at as low a heat as was feasible. This often proved to be a tedious operation. The solution containing the alkalies was evaporated to dryness in a platinum dish after the addition of the insoluble portion and enough ammonic carbonate to convert the calcic oxide formed into calcic carbonate. The ash was eventually dried at 200 degrees C., at last with addition of solid ammonic carbonate and bottled while still hot and carefully corked. If the ash thus prepared has to be kept for any length of time, it is necessary that it should be sealed. This degree of care was taken to avoid loss of chlorine and also possibly of sulphur. During the course of the preparation, however, we became convinced that the precautions taken were inadequate, because the loss of chlorine was not due to the volatilization of the sodic or potassic chlorides, but due to the formation of ammonic chloride. The odor of ammonia was very marked at certain stages of the process and was present in sufficient quantities to react upon red litmus paper, and a glass cylin-

der, placed over the already charred mass became coated with a white film whose solution in distilled water reacted strongly for chlorine. The temperature of the mass was at this time very low, and the escape of the potassic and sodic chlorides from the mass, whose surface was covered with a layer of already cooled ash, even if the temperature at the glowing points was high enough to volatilize them, is difficult to believe. But one proof has already been adduced, that with this highly nitrogenous plant, chlorine did escape, whatever may be the facts relative to the sodium and potassium. The loss of chlorine was also noted by direct observations in the incineration of a sample of seed, but the conditions were not similar and the film of chloride, collected on the cool platinum foil used in this instance, may have been the chloride of one of the fixed alkalies, or perhaps of both. No less care had to be exercise to avoid the formation of the alkaline sulphides either directly or by reduction of the sulphates, principally, if not exclusively, by the latter process. Close observation shows that, if the combustion is slow enough to avoid a high temperature in any part of the mass, there will be no sulphides formed, but otherwise yellow points may be detected in the mass by careful examination before it has been stirred too much. In burning large quantities it is almost impossible to avoid its formation because of our inability to control the rate of combustion in all parts of the mass.

The time consumed in preparing the samples of ash was very great, and, as we shall subsequently see, did not produce results commensurate with the care bestowed upon it. The only point in which satisfactory results were obtained was in producing an ash practically free from carbon and one in which we had no free bases, either lime or alkalies. The evaporation of the ammonic carbonate solution to dryness and heating to 200 degrees C., with the addition of the insoluble, was probably without any other effect than to assure the conversion of any caustic lime into the carbonate. That it may have been the cause of the loss of any chlorine ors ulphuric acid, particularly the latter, is very doubtful. This question suggested itself, and calcic sulplate was repeatedly heated in this manner without change in weight.

THE METHODS OF ANALYSES.

As the methods adopted in this work are not identical with those commended by the Association of Official Agricultural Chemists, we deem it just to give the methods used, which, in our hands, are convenient and very satisfactory. The general method was to dissolve 4-5 grams of the

ash in hydrochloric acid and to separate the silicic acid by evaporating to dryness and heating in an air bath at 115 to 120 degrees for two hours, after which the mass was wet with strong hydrochloric acid and evaporated to dryness again on the water-bath, taken up with water and as little hydrocholoric acid as possible, and the solution made up to 250 c. c. The soluble silicic acid was separated from the sand and carbon by means of caustic potash solution. The sand, etc., was washed from the filter into a platinum dish, a solution of caustic potash, corresponding to three grams of the solid salt, was added, and the whole evaporated to dryness on the water-bath. This gives us fixed conditions for all the analyses. Fresenius and Will have shown that sand is not attacked under these conditions. There was not carbon enough in any sample of ash analyzed to give any trouble and the solutions were clear and colorless. The residue, insoluble in caustic potash, was washed with hydrochloric acid and subsequently with water until free from chlorine and weighed on a tared filter. The carbon was burned off and the sand weighed. The silicic acid was separated from the potash solution as usual and weighed as silica. One portion of the solution, corresponding to about one gram of ash, was taken from the determination of the sulphuric acid, oxide of iron, and alumina. A second portion, equal to the first, was taken for the phosphoric acid, manganic oxide, lime and magnesia, and a third one for the determination of the alkalies. The sulphuric acid was thrown down as baric sulphate from the boiling solution by hot dilute baric chloride solution ; this precipitate was filtered off, washed until no chlorine could be detected in the wash water, ignited, and as a precaution, weighed. It was then fused with sodic carbonate or sodic-potassic carbonate—the solution of the sulphate must be complete—whereby the excess of barium and any iron and alumina is separated, the solution was acidulated with hydrochloric acid and after standing until the excess of carbonic oxide had escaped, was heated to boiling, and the sulphuric acid again precipitated by a hot dilute solution of baric chloride; this precipitate was washed and weighed, then dissolved in concentrated sulphuric acid, and the baric sulphate cystallized by evaporation to dryness and washed with boiling water. The fusion, with the alkaline carbonates, is advisable to remove excessive baric salts, iron and alumina, the solution in sulphuric acid to remove alkaline salts from the baric sulphate. These operations lengthen the analyses, but the results are very different from the first weights obtained in the determinations.

The ferric and aluminic phosphates were thrown down from the filtrate by means of ammonia, and acetic acid added to dissolve the other phosphates. This precipitation had to be repeated at least three times to get rid of baric and calcic phosphates. There was not maganese enough in any sample analyzed to come down with ferric and aluminic phosphates in sufficient quantity to be detected. The ferric oxide was separated by means of citric acid, ammonia and ammonic sulphide. If the precipitate of phosphates is not heated too strongly, even partial fusion must be avoided, their solution in hydrochloric acid is easily effected, and the separation is easily performed.

PHOSPHORIC ACID, MANGANESE, LIME AND MAGNESIA.

A quantity of pure ferric chloride, sufficient to combine with all the phosphoric acid, was added and then, if the solution was not too acid, solid sodic acetate sufficient to convert all the bases into acetates, and the whole evaporated to dryness on the water-bath. If the solution was too acid, it was partly neutralized with sodic carbonate before the addition of the acetate. The dry mass was moistened with acetic acid and boiled out with water. As a rule, I do not wash this precipitate thoroughly, but dissolve it in hydrochloric acid and evaporate the second time with the addition of sodic acetate. The precipitate contains neither manganese, lime nor magnesia and the solution is free from iron and alumina, from which no trouble is experienced in precipitating even traces of maganese by bromine water, and has the further advantage of being small in volume. The lime was precipitated as oxalate, with the ordinary precautions, to obtain its complete precipitation. I allowed it to stand as long as at all convenient, washed and dried it partially and ignited it in a platinum crucible or dish until all the oxalate was destroyed; it was then brought into solution and reprecipitated as oxalate. This precipitate was free from magnesia. The filtrates containing the magnesia were evaporated to a convenient volume and the magnesia thrown down by ammonic phosphate; this precipitate was purified by solution and reprecipitation. A nitric acid solution of the precipitate of ferric oxide, containing the phosphoric acid, was obtained either by dissolving it in nitric acid directly, or by first dissolving it in hydrochloric acid, precipitating by ammonia, washing and then dissolving it in nitric acid. The latter method will be found the shorter, as a rule, and more satisfactory. The phosphoric acid was thrown down from this solution by ammonic molybdate, the precipitate washed with dilute nitric acid, dissolved in am-

monia, and precipitated with magnesia mixture. The precipitate was allowed to stand, though precipitated hot with the aid of violent stirring, for twelve hours, and then, after washing, dissolved and precipitated, often with the addition of a little citric acid if there was any suggestion of the presence of ferric phosphate in the phospho-molybdic acid. The third portion of the solution was used for the determination of the alkalies. I added to the boiling solution baric chloride, enough to precipitate the sulphuric acid, and ferric chloride to combine all of the phosphoric acid and then washed milk of lime to alkaline reaction, washing the precipitate free from chlorine. If too much milk of lime is added this is rendered much more difficult. I prefer to add no more milk of lime than is necessary to precipitate the ferric salts and render the solution alkaline, filter and wash out the precipitate, add lime water to filtrate and evaporate down to a small volume, filtering off the magnesic and calcic salts which separate before precipitating with ammonic carbonate; by which, together with a little oxlate of ammonia, the lime was removed. The last portions of the lime are removed as usual. The addition of baric salts makes this portion of the operation more difficult, but if more than traces or only small quantities of sulphuric acid are present, the addition of baric chloride is advisable. The potassic-platinic chloride was uniformly dissolved in boiling dilute hydrochloric acid and crystallized by evaporation on the water-bath. If enough hydrochloric acid is added, there will be no trouble experienced by the formation of a crystalline film to prevent evaporation; on the contrary, the salt will crystalize in large, well defined crystals, as good as free from water, if not entirely so. The potassic-platinic salt was weighed on a tared filter after drying in the water-oven for not less than two and one-half hours.

CHLORINE AND SULPHUR.

The chlorine was determined in two ways; first, from the ash and second from the plant. I was induced to do this by two observations, the first of which has already been given, i. e., an observed loss of chlorine; and the second was the fact that I obtained such unusually high percentages of chlorine in the different ashes that I at first felt that probably I had made some mistake, particularly so as there was not even an approximate agreement between the results obtained from what would be considered comparable samples. The first method was, to dissolve a weighed portion of ash in cold dilute nitric acid with imme-

diate addition of argentic nitrate, and sometimes I used a mixture of argentic nitrate and nitric acid as the solvent. The argentic chloride was dissolved in ammonic hydrate, filtered and thrown down by nitric acid and eventually weighed on a tared filter. The very highest result that I could find given for chlorine in the ash of this plant was a little over eight per cent., and the usual quantity given was about two per cent. or less; and still finding from five to six and even eight per cent., although I knew that chlorine had been lost in preparing the ash, I concluded that I was in error and resolved to determine the chlorine in the plant or dried sample. To this end from ten to thirty grams was taken, from two and one-half to eight grams of pure sodic carbonate was dissolved in water and made up to a volume sufficient to wet the sample thoroughly. The sample was then placed over a free flame and thoroughly charred, the mass being extracted with hot water; the filtrate was usually slightly colored, especially in cases where a larger portion had been taken, but when the charring had been successfully done, the solution was colorless. The carbon was washed free from chlorine and then burned until the ash was white. As the organic matter is an unpleasant material to have in the solution, I evaporated the same to dryness and ignited it to complete the carbonization. This was easily effected at a temperature which would produce no volatization of the sodic chloride from the mixed salts. The solution was filtered off and added to the nitric acid solution of that portion of the ash insoluble in water. As a matter of course, care was taken to avoid loss from effervescence, escape of hydrochloric acid, etc. From this point on the two processes were the same, but the results were much higher than before. This induced me to treat the whole series in this manner. It has been stated that a loss of chlorine can scarcely be avoided in incinerating the plants; but either the loss has been considered insignificant or the determination of chlorine has been deemed of so little importance to our study of the plant's requirements that the determination of chlorine in the ash has been accepted, perhaps with good reason, as quite sufficient for our purposes. Be this as it may, we have made the series of determinations in which our results approximate closely to the chlorine in the plants at the time they were cut; and, while the loss is very varying, it is observable in every case and shows that the amount of care bestowed upon the preparation of the ash was not sufficient to give us more than a relative idea of the amount of this element in the plant. The results are expressed in the per-

centage of ash found in the air-dried samples, and contain a small error which may, in this case, be neglected. The results are grouped so as to show the chlorine in different parts of the plant, as well as the differences in the results of the two methods of analysis. The samples from the same locality are brought together as far as convenient.

The first column gives the percentage of chlorine found in the ash, and the second the amount corresponding to that obtained from the plant, calculated on the basis of the per cent. of ash found in the air-dried samples.

Hay Samples.

Coming in bloom, 2nd cut	7.758	8.670
Full bloom	8.500	10.880
Half bloom, 2nd cut	7.919	9.637
More than half bloom, 1st cut	7.010	8.888
With seed formed, 1st cut	8.150	9.609
With seed formed, 1st cut	5.760	7.166
Stubble	1.598	2.762
Not in full bloom, 1st cut	4.036	5.665
Half bloom, 1st cut	3.358	4.201
Full bloom, 1st cut	6.020	6.531
Red clover	2.500	2.527
Not in bloom	8.311	9.457
Third cutting	4.753	5.161
Third cutting	7.727	8.180
Some seed formed, 1st cut	6.776	7.966

Parts of Plant.

Whole roots, washed	.523	.746
Whole roots, washed	.318	.609
Whole roots, not washed	.985	1.357
Whole roots, not washed	1.322	1.615
Outside portion of roots	1.226	2.000
Outside portion of roots	1.771	2.333
Inside portion of roots	.756	1.151
Inside portion of roots	.603	1.375
Stems		5.988
Stems	8.510	9.923
Stems	8.180	9.667
Leaves	4.835	.....
Leaves	6.463	7.388
Leaves	6.246	6.773
Leaves	4.822	5.941
Flowers	4.881	.....
Seed	.767	1.453

The ash of the stems appears to contain the highest percentage of chlorine, but that of the leaves by far the

largest quantity, as they have an average ash content of about 13.5 per cent., against 5 per cent. in the stems; the roots and seed have but little, both the percentage of ash and its content of chlorine being small.

I have one sample of red clover grown under conditions identical with those under which one of the alfalfa samples was grown, and is therefore comparable with it. The clover contains 10.07 per cent. ash, with only 2.5 per cent. chlorine; while the alfalfa hay grown under the same conditions has 10.42 per cent. of ash with 6.53 per cent. of chlorine.

According to E. Wolff as quoted by Mayer in his Agrikulturchemie, red clover ash contains 3.95 per cent., and alfalfa ash 3.48 per cent. of chlorine; while E. Wolff, in his ash analyses, gives 2.57 for the percentage of chlorine in alfalfa ash from plants in bloom. The difference between these determinations may be accidental and I regret that I have not enough of the sample to either establish the fact, for instance, that alfalfa does require more chlorine for its proper maturing than clover does, or that this result is an accident. As it is the result is suggestive only. It ought to be remarked here that alfalfa does better throughout this country than clover does, although good crops of clover can be grown here. I never saw a finer specimen of red clover than the one used in this determination. The chlorine may have a very important function in the development of alfalfa, and hence its large amount, this may or may not be the proper explanation, but it is evident that the ordinary method of preparing the ash gives too low results and, after allowing for differences due to differences of soils, we have differences due to the degree of maturity; but in all the samples the percentage is high. I have found but few analyses that are nearly as high. Wolff gives three with 6.97, 7.00 and 8.05 per cent. chlorine. Harrington, in Texas bulletin No. 20, also gives three, with 5.07, 6.90 and 8.57; while the average percentage in the ash of alfalfa hay, as we have found it, is 7.85 per cent., with 10.88 per cent. as a maximum and 4.20 per cent. as a minimum.

The sulphur was determined and estimated as sulphuric acid. That some of the sulphur may escape as sulphuretted hydrogen on dissolving the ash in hydrochloric acid, is a well-known and an almost hackneyed observation. As the albuminoids which may contain sulphur are abundant, and also as the alfalfa is a lime loving plant (its leaves containing an abundance of calcic sulphate), the sulphur seems to promise as great a loss as the chlorine. As my time did not permit of an extended series of experiments in

this line; and further because of the tedious character of the operations, only a few samples were chosen in which to attempt the more accurate determination of these components, sulphuric and phosphoric acids. Two samples of roots and one of leaves were chosen for this work; the leaves because of the large amount of sulphuric acid, and the roots because of their relative richness in phosphoric acid as well as low percentage of ash.

In the following table, the first column gives the percentage of sulphuric and phosphoric acids found in the ash, and the second column gives the percentage which the ash should contain to correspond to the percentage found in the plant.

Leaves:—		
Sulphuric acid	10.841	12.843
Phosphoric acid	3.459	3.600
Inside portion of roots:—		
Sulphuric acid	4.881	8.091
Phosphoric acid	16.032	15.982
Whole roots:—		
Sulphuric acid	5.093	7.653
Phosphoric acid	10.270	10.048

Here we observe a loss of 2.001, 3.210, and 2.561 per cent. of sulphuric acid; while the phosphoric acid determinations agree as well as could be expected. The preparation of the ash samples has been given. The determination directly from the air-dried samples was made as follows: from ten to thirty grams of the sample, according to the amount of ash it had yielded, was placed in a silver dish and thoroughly saturated with a solution of a mixture of ten grams potassic hydrate to two and one-half grams of nitre and ignited with subsequent addition of weighed portions of nitre until the mass had become white. The sulphuric acid in the potassic hydrate and nitrate was determined and deducted from the total found. Every precaution heretofore given was exercised in these determinations of sulphuric acid, and equally so in the case of the phosphoric acid, which was thrown down from the filtrate from the baric sulphate as ferric phosphate and then by ammonic molybdate as usual.

These results make evident the error in the sulphuric acid determinations by the method of direct incineration as given for these samples; but show no loss for the phosphoric acid. These were the primary objects of the determination, but the samples were chosen with the purpose of giving duplicate determinations of these constituents, partic-

ularly of the sulphuric acid in the ash of the leaves and of the phosphoric acid in that of the roots, which seemed anomalously high, but the correctness of the other determinations was more than fully established in this far, that the ash of the leaves contains large quantities of sulphuric acid, and that that of the roots is next to that of the seed in richness in phosphoric acid. The leaves are rich in albuminoids, chlorine, and sulphuric acid. We have no where made any distinction between sulphur and sulphuric acid, and, though it is probable that a large proportion of the sulphur is present in the leaves as sulphate of lime, it is certainly not all present as such. There are two ways of explaining this that suggest themselves to the ordinary mind: either they are simply accumulated there, being brought here more rapidly than they can be disposed of by the plant, or they are gathered there for some functional purpose. The decision of this matter we leave to the physiological botanist; but until we learn better we shall continue to think it more probable that it is for the functional purpose rather than the result of simple accumulation.

Reference has been made in the bulletin proper to the attempt to determine the nitric nitrogen in alfalfa hay. The reducing agent used was neither of those recommended for this purpose; but was metallic iron in conjunction with precipitated copper. I have found this a most convenient and efficient reducing agent for converting nitric acid into ammonia and have given it preference in this work. I am not aware that this has been recommended by any one previous to this time. I added two grams of crystallized cupric sulphate and one and one-half to two grams of reduced iron. As this will give from 13.78 per cent. to 13.83 per cent. of nitrogen in potassic nitrate, I deemed it of sufficient delicacy to give reliable indications in this investigation and have already given the results obtained.

All methods not given in this appendix were the conventional methods.

The fodder analyses were made by Mr. Ryan; also the soil analyses. All others were made by myself.

We have brought together in the following tables our own analyses of alfalfa hay and separate parts of the plant, calculated on the basis of dry matter; also all the analyses of other stations so far as we have been able to find them. Many of these are given in the original publications as analyses of hay; others as analyses of the green plant; and still others in the form here adopted. Of course, all of the first two classes appear here in different percentages from those in the originals.

The writer is not familiar with the conditions in California, Texas, etc., but the results of the analyses show in some cases most remarkable differences. With us in Colorado, the youngest plants analyzed (cut while very immature--May 5th—from three to four weeks before blooming), show 25.72 and 31.52 per cent. of crude fiber for two different types of plants. These are the lowest percentages obtained by us for crude fiber from any Colorado sample; but none of the New Jersey samples reach 25 per cent. The Texas samples vary greatly, and the Kentucky samples are all below 25.2 per cent. The fat in these samples is from two to four fold that found in our samples, and the nitrogen free extract is as a rule higher, though in some cases it is lower. Those of all the samples which approach nearest to Colorado alfalfa are given by the Massachusetts Experiment Station. There are two points in which all the analyses agree, i. e., in showing high percentages of ash and proteids, the latter reaching its maximum in the Texas samples, followed closely by the Kentucky and Georgia samples; while the Colorado samples are very low in the series, the single samples from California and Vermont being the only ones below them in this respect.

It is futile for a person unacquainted with the soil conditions, the climate, the cultivation, and every detail of the conditions under which the plants were grown, the stage of development of the plants at the time of cutting, treatment of samples, etc., and even to these are to be added other very imperfectly understood factors, to attempt to explain the causes of the differences in the samples. The distance between Cape Ann and New Brunswick, N. J., is nearly the same as that between Fort Collins and Rocky Ford, and from New Brunswick to Raleigh, N. C., is about twice as far, while the latitude of New Brunswick and Fort Collins differs by only about one degree. Yet, the samples from Massachusetts and North Carolina are nearly identical with the Colorado samples; while the New Jersey samples differ very materially from them. We have four samples grown in different climates and soils; three of them agree in composition and the fourth one differs. The differences are not so marked in the other samples. I have found no complete analyses of alfalfa ash in any of the Station bulletins; the only ones that I have noted being four partial analyses given in Texas Bulletin No. 20, and two in Massachusetts State Experiment Station Report for 1888. These analyses were made with reference to the fertilizing value of the mineral constituents contained in them and not to determine all of the ash components.

FODDER ANALYSES.

	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.
FIRST CUTTING.						
Cut very young	......	......	22.890	25.720	......	3.318
Cut very young	......	......	21 030	31.520	......	3.365
Not in bloom	10.66	2.020	16.270	36.700	34.345	2.604
Not in bloom	10.54	2.011	16.275	37.180	33.895	2.604
Not in bloom	9.92	1.650	17.120	40.580	30.730	2.740
Not in bloom	9.82	1.740	17.120	40.920	30.400	2.740
In half bloom	9.89	1.260	15.370	38.880	34.600	2.549
In half bloom	10.06	1.610	15.370	38.530	34.430	2.549
In full bloom	9.68	2.300	15.304	......	......	2.420
In full bloom	9.88	2.240	15.304	38.500	34.760	2.420
In full bloom	10.53	1.250	15.027	42.880	30.313	2.404
In full bloom	10.43	1.360	15.027	42.670	30.513	2.404
In full bloom	10.71	1.530	15.660	36.110	35.990	2.506
In full bloom	10.81	1.730	15.840	36.390	35.230	2.534
In full bloom	11.01	1.664	16.020	35.380	35.930	2.566
In full bloom	11.19	1.622	15.490	34.590	37.110	2.478
In full bloom	11.41	1.450	15.840	36.900	34.400	2.534
In full bloom	11.55	1.510	16.190	36.520	34.230	2.590
In full bloom	12.27	1.810	17.240	34.590	34.070	2.758
In full bloom	12.20	1.640	16.360	33.900	34.900	2.618
In full seed	7.11	1.080	12.812	48.390	30.610	2.050
In full seed	7.41	.960	12.656	48.380	30.590	2.025
In full seed	10.24	2.060	14.690	40.800	32.210	2.350
In full seed	10.44	2.210	15.310	39.450	32.590	2.450
SECOND CUTTING.						
Not in bloom	11.23	1.340	17.560	30.860	38 810	2.810
Not in bloom	10.91	1.610	16.670	30.920	39.890	2.670
Coming in bloom	12.50	1.190	18.820	33.950	33.540	3.011
Coming in bloom	12.44	1.190	18.850	34.320	33.200	3.018
Half bloom	11.31	1.260	16.080	39.880	31.470	2.572
Full bloom	10.01	1.600	13.781	39.480	35.129	2.205
Full bloom	9.90	1.430	13.781	38.910	35.979	2.205
Full bloom	11.47	1.840	13.240	39.770	33.680	2.119
Full bloom	11.50	1.860	13.630	39.570	33.490	2.180
Early seed	9.56	1.220	12.580	33.200	43.440	2.013
Early seed	9.68	1.220	12.580	33.520	43.000	2.013
THIRD CUTTING.						
Hay from College farm	9.09	1.710	13.000	39.550	36.650	2.080
Hay from College farm	8.66	1.710	13.060	39 160	37.410	1.930
Hay from Rocky Ford	10.47	1.380	12.910	34.670	40.570	2.064
Hay from Rocky Ford	10.08	1.410	12.680	33.880	41.950	2.029
PARTS OF PLANT.						
Seed	3.15	15.230	31.340	22.540	27.640	5.014
Seed	3.19	15.400	31.700	22.570	27.170	5.072
Flowers	9.85	2.210	22.350	20.850	44.740	3.576
Flowers	10.20	......	22.350	21.090	......	3.576
Leaves	15.19	3.020	20.730	16.920	44.140	3.319
Leaves.	15.19	3.190	20.730	16.720	44.170	3.319
Leaves.	12.48	4.690	24.300	13.650	44.880	3.892
Leaves.	12.48	4.690	25.290	13.650	44.090	4.046
Leaves.	14.84	4.770	24.240	11.370	44.780	3.878

FODDER ANALYSES—CONCLUDED.

	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen Free Extract.	Total Nitrogen.
Leaves..........	14.61	3.750	24.690	11.650	44.300	3.950
Leaves..........	15.03	3.078	25.500	13.760	42.630	4.088
Leaves..........	15.54	3.109	24.500	13.830	43.420	3.920
Stems	5.19	.953	6.480	57.510	29 870	1.035
Stems	5.30	.900	6.470	57.610	29.720	1.035
Stubble, includes 6½ in. of the roots..	4.47	.518	12.160	38.190	45.000	1.945
Stubble, includes 6½ in. of the roots..	4.51	.610	11.750	37.400	45.730	1.880
Roots..........	3.90	.760	11.500	26.530	57.310	1.758
Roots..........	4.04	.680	11.210	26.120	57.950	1.717
Roots..........	3.88	1.090	10.690	25.430	58.910	1.710
Roots..........	3.89	1.190	10.640	25.490	58.790	1.703
Barks of roots..........	5.40	2.160	14.750	22.790	54.850	2.360
Inside portion of roots	3.64	2.920	8.000	30.330	55.140	1.280

COMPILED ANALYSES.

	Ash.	Ether Extract	Crude Protein	Crude Fiber.	Nitrogen Free Extract	Total Nitrogen.	
Fertilized	7.97	1.12	16.27	34.39	40.25	2.603	Mass. State Expt. Sta.
Not fertilized..........	7.10	1.04	14.41	32 41	45.04	2.306	Mass. Rep. 1888, p. 165.
No description given	8 25	4.47	12.60	32.94	41.74	2.020	Vt. Rep., 1891, p. 49.
Drilled, 1st cut..........	9.88	4.34	20.30	24.34	41.14	3.240	New Jersey Rep., 1888
" 2nd cut..........	7.89	3.73	15.24	18.36	54.78	2.438	" " " "
" 3rd cut	9.19	4.22	17.72	18.24	50.63	2.835	" " " "
" 4th cut	10.55	5.14	21.72	21.06	41.53	3.475	" " " "
Broadcast, 1st cut..........	10.52	4.07	20.73	23.11	41.57	3.316	" " " "
" 2nd cut..........	8.22	3.24	16.76	23.70	48.08	2.681	" " " "
" 3rd cut	9.80	0.69	17.64	21.60	50.27	2.822	" " " "
" 4th cut	10.42	5.81	19.64	21.58	42.55	3.142	" " " "
Cut April 20, irrigated....	12.91	6.14	18.13	27.56	35.27	2.900	Texas Bul. No. 20, 1892
" " 29, irrigated....	12.30	5.18	19.93	29.87	32.72	3.190	" " " "
" May 11, irrigated....	10.34	4.87	19.18	33.61	31.98	3.070	" " " "
" " 30, irrigated....	8.00	3.61	15.31	34.23	38.85	2.450	" " " "
" " 30, 2nd cut......	15.26	3.10	23.56	25.20	32.88	3.770	" " " "
" April 3, not irrigated	10.94	6.30	25.75	16.64	40.37	4.120	" " " "
" " 21, not irrigated	10.59	7.25	25.68	22.98	33.50	4.110	" " " "
" May 11, not irrigated.	8.04	6.60	17.37	30.25	37.70	2.780	" " " "
Flowers begin to appear..	11.85	4.48	23.38	19.76	40.53	3.140	Ky. Rep., 1889-90, p. 19
In bloom..........	7.72	3.00	16.86	25.15	47.27	2 698	" " " "
Pods formed..........	9.67	2.07	14.83	25.19	48.22	2.405	" " " "
* No description given....	7.93	2.49	17.42	33.54	38.62	2.787	N. C. Rep., 1889, p. 82
† Sample inferior hay. ...	5.79	1.66	9.06	39.97	43.52	1.450	Cala. Rep., '91-2, p. 125
No description given.... ..	4.28	2.22	21.86	29.55	42.09	3.498	Ga. Bul. No 7., 1890.
No description given......	7.87	2.66	16.24	31.08	42.15	2.569	N. Y. State Rep. 1889
Beginning to bloom	10.5	2.5	16 3	25.4	45.3		Mass. State Expt. Rep. '85, p 70
First cut (b)	9.3	2.6	20.1	28.3	39.7		N. J. Exp. Sta. Rep, 1886, p. 160
Second cut (b)..........	6.9	1.9	18.6	35.0	37.6		" " " " " "
Third cut (b)..........	6.6	2.1	16.0	33.5	41.8		" " " " " "
In bloom. 1st cut fertiliz'd	7.2	1.5	11.1	28.5	51.7		Mass. St. Exp. Rep. '87, p. 131
" " " not fert'z'd	7.8	2.0	13.0	27.9	49.3		" " " " " "
Coming into bloom......	8.8	2.2	18.8	30.1	40.1		Vt. Expt. Sta. Rep. 1887, p. 130
Seed in dough..........	8.6	2 4	16.1	32.8	40.1		" " " " " "
Time of cutting unknown	8.1	3.2	16.6	24.2	27.9		Colorado Expt. Sta. Bul. 8, 1889
‡Third cut, not irrigated..	11.5	3 0	21.9	18.6	45.0		" " " " "
Cut for seed, Sept. 25.....	7.9	4.2	12.3	24.5	51.1		" " " " "
Third cut, very coarse.....	9 1	2.4	12.2	26.3	50.0		" " " " "
Cut July 15, in bloom.....	11.2	2.5	11.6	15.4	59.3		" " " " "
" June 6, not irrigated .	9.8	2.8	13.5	21.0	52.9		" " " " "
" July 25, irrigat'd twice	7.9	2.0	12.4	25.0	52.7		" " " " "
" July 25, irrigated once	8.5	2.9	11.3	24.1	53.2		" " " " "
Second cut..........	8.8	2.7	12.9	22.2	53.4		" " " " "

* The analysis of the North Carolina sample, as it appears in their report, contains a typographical error, as the analysis shows an excess of 5 per cent. I have assumed that the error was in the nitrogen free extract, and have re-calculated the analysis giving the percentages on the basis of dry matter.

† The writer of the article in the California report states that the sample was mostly stems and that it was not a fair sample of California alfalfa hay. ‡ 26 days from time of previous cutting.

ANALYSES OF ALFALFA ASH.*

	Carbon.	Sand.	SiO_2.	P_2O_5.	SO_3.	Cl.	CaO.	MgO.	Fe_2O_3.	Al_2O_3.	Mn_3O_4.	K_2O.	Na_2O.	CO_2.	Sum.	Less O = Cl.	Total.
FIRST CUTTING.																	
Not in bloom	.031	1.087	1.181	5.028	4.440	8.311	22.833	3.223	.378	.162	.166	30.346	1.199	23.559	101.944	1.872	100.072
Not in bloom	trace	.781	1.150	4.630	4.965	4.063	24.750	3.806	.440	.166	.123	29.712	1.423	24.513	100.529	.915	99.614
Half bloom	''	.656	1.065	4.713	5.068	3.358	24.880	3.833	.337	.187	.123	29.892	1.652	25.361	101.125	.766	100.359
Full bloom	.112	.829	.881	5.234	5.608	8.500	27.620	3.798	.269	.089	.168	24.240	.913	23.730	102.220	1.920	100.300
Full bloom	.110	1.370	1.810	4 050	3.440	6.020	25.870	3.810	.090	....	.060	28.380	.860	25.200	101.070	1.350	99.720
In full seed	trace	2.142	1.083	5.404	4.216	5.760	20.146	4.462	.407	.241	.239	28.017	4 039	25.134	101 290	1.289	99.992
In full seed	''	1.765	1.503	4.459	5.635	6.776	23.905	5.951	.397	.253	.188	23.934	1,840	25.151	101.768	1.523	100.245
SECOND CUTTING																	
Coming in bloom	''	.982	.776	3.941	6.114	7.758	25.973	3.373	.301	.055	.193	25.376	1.860	24.766	101.468	1.749	99.719
Half bloom	''	.907	.584	4.633	7.073	7.919	25.610	3.678	.249	.104	.149	26.865	1.756	22.606	102.133	2.003	100.130
Full bloom	.070	1.590	1.600	4.600	4.530	7.010	29.810	4.500	.140	.300	.080	21 340	1.020	24.440	101.030	1.580	99.450
Full bloom	.090	1.580	1.300	4.590	4.710	7.010	29.670	4.440	.100	.300	.110	21.250	1.050	24.440	100.640	1.580	99.060
Full bloom	.080	1 590	1.450	4.600	4.620	7.010	29.740	4.440	.021	.300	.090	21.300	1.040	24.440	100.850	1.580	99.270
Full bloom	.286	1.761	.850	4.519	6.640	8.150	26.273	4.033	.335	.171	.188	24.112	.991	23.625	101.934	1.836	100.098
THIRD CUTTING.																	
Hay	.011	.608	.431	3.903	3.551	4.753	21.497	4.142	.195	.092	.122	28.395	4.890	28.413	101.003	1.070	99.923
Hay	.020	1.216	.858	3.714	5.477	7.721	24.524	3.141	.397	.189	.156	28.209	2.055	24.003	101.680	1.739	99.941
PARTS OF PLANT.																	
Seed	trace	1.470	.640	38.863	1.370	.767	5.379	9.542	.485	.095	.209	35.213	1.547	4.536	100.116	.172	99.944
Flowers	''	9.187	3.157	7.702	6.256	4.881	16.949	3.953	1.013	1.179	.203	25.586	4.024	.....	....	.	.....
Leaves	.023	4.104	1.844	3.013	11.520	4.835	31.327	5.259	.562	.594	.218	9.101	3.722	....	....	....	......
Leaves	trace	.498	.866	4.399	11.241	6.463	28.435	4.642	.294	.208	trace	18.310	3.797	22.327	101.480	1.456	100.024
Leaves	''	.728	.767	3.407	6.246	6.697	38.370	4.266	.440	.103	.194	11.585	.777	28.113	101.693	1.509	100.184
Leaves	''	.524	.818	3.459	10.841	4.822	35.643	4.536	.430	.098	.315	10.905	3.641	24.031	100.064	1.086	98.978
Stems	''	1.727	1.604	4.437	3.492	5.988	14.260	5.261	.479	.488	.163	26.851	8.335	......	. ...	....	......
Stems	''	1.227	1 171	6.060	2.085	8.511	14.660	4.688	.545	.290	.157	33.487	4.522	24.368	101.771	1.915	99.856
Stems	''	.754	1.541	4.961	1.904	8.180	17.713	4.360	.362	.369	.145	36.688	1.093	23.858	101.928	1.802	100.124
Stubble	''	4.540	2.673	10.010	3 040	1.598	21.280	6.471	1.044	.697	.262	18.705	5.550	23.895	99.765	.360	99.405
Roots	''	5.907	3.561	8.888	3.208	.523	18.241	8.374	1.147	1.348	.357	22.474	2.469	23.567	100.154	.119	100.037
Roots	''	9.277	4.011	6.359	2.014	.318	21.208	5.481	1.689	1.188	.573	20.331	1.127	26.567	100.143	.038	100.105
Roots	''	2.058	3.865	11.821	5.337	.985	13.949	6.716	1.275	1.182	.681	29.784	5.355	17.630	100.638	.221	100.417
Roots	''	2.380	2.875	10.270	5.093	1.322	19.008	9.492	.844	.729	.149	24.443	2.110	21.742	100.457	.299	100.158
Bark of roots	''	5.119	6.045	9.375	6.318	1.226	14.357	6.563	1.430	1.619	.267	26.122	5.896	16.001	100.338	.276	100.062
Bark of roots	''	5.527	4.670	8.389	6.244	1.771	16.012	10.885	.993	1.444	.400	22.447	2.187	18.268	99.327	.398	98.929
Inside of roots	''	.860	1.125	11.144	4.973	.751	14.159	11.757	.675	1.148	.218	23.037	7.214	23.065	99.126	.169	98.957
Inside of roots	''	1.163	1.072	16.032	4.881	.603	21.021	12.148	.525	.235	.290	18.675	2.424	21.177	100.246	.135	100.111
Red clover	.120	1.730	1.950	2.890	1.330	2.500	25.330	5.550	.100	.....	.210	26.800	.230	30.640	100.380	.360	100.020

* Lithia was not detected in any sample, but strontia was present in all of them,

PLATE I.

The plant represented in this plate grew in a rich, loose soil, with a heavy clay subsoil and an abundant supply of water, the water level ranging from 4 to 8 feet from the surface at different seasons of the year. The diameter of the top was 18 inches, and the number of stems 360. The plate shows how these crowns gather soil around them, for the length of the underground stems is seen to be several inches, and this represents the accumulation of nearly this much material about it.

This is one of the largest plants that I have yet found. The specimen, as photographed, was dug April 30th, 1896.

PLATE II.

This photograph represents the face of an opening made to the depth of rather more than 13 feet in an alfalfa field on the Experiment Station Farm, at Rocky Ford, Otero County, Colorado. The soil is a fine alluvium. The roots penetrated to a depth of 12 feet 6 inches, and the simplicity of the root system is well shown, the roots being shown in their natural position. The upper margin of the photograph represents the surface of the ground, which lacks sufficient sharpness to show the crowns and stubble in the picture.

This alfalfa was four years old and cut from four to five tons of hay a year. The diameter of these roots, just below the crown, averaged a little less than ½ inch.

PLATES III. AND IV.

The two succeeding plates represent the largest alfalfa roots that I have seen. The root system and the tap roots are exceedingly large; they were of very nearly the same length—11 feet 9 inches—measuring from the crown of the root to the deepest point to which the roots had penetrated. They were not dug at the same time and are different types of roots. The tops of these plants measured over 5 feet 3 inches. They were obtained on the place of Mr. J. H. Walter, in Weld County, Colorado.

PLATES V. AND VI.

The two succeeding plates represent typical roots, grown on the place of Mr. J. H. Walter, in Weld County, Colorado. The smaller roots have been placed as nearly in the relative position which they had when taken from the soil as possible. These roots were very large, having a diameter below the crown of 1 inch. Unfortunately it was impossible to have the plants photographed immediately after digging them, and the leaves have fallen from the stems.

PLATE VII.

This cut represents an unusual form for an alfalfa root. It has not arisen from the tap root having received an injury at some time, for it is present, as may be seen upon close inspection, in perfect condition. It is difficult to distinguish between the branches of this root; they have about the same size and length, and one of them would serve as well for the tap root as any other. The root seems to have divided into five roots a little below the crown, each division going down separately, as an independent root, instead of going down as a single tap root. The length of this root was nearly 11 feet.

PLATE VIII.

This plate shows a root with more than the usual amount of branching, also the crown as dead on one side and developing on the other. The particular and anomalous feature about it is the throwing out of the two small roots at the crown. This is one of the very few instances of this which I have seen. In this case, as in all others which I have seen, these roots, although small in diameter, are as long as the larger roots.

PLATE IX.

Yearling plants grown on a highly cultivated soil: the maximum depth to which any of them had penetrated was 3 feet 9 inches. The soil was a fine prairie loam, with a clayey subsoil, succeeded by a fine yellow sand. This soil offered no resistance to the growth of the roots. The black spot on one of the roots is the remnant of a dead root, which, having died and decayed, left an open channel which the alfalfa root had followed. I have traced alfalfa roots for four and five feet where they have followed the course of decayed willow roots.

PLATE X.

These roots had a length of 9 feet 4¾ inches and were nine months old. The field had been sown to alfalfa with oats in the spring, and one cutting of alfalfa hay was made in the fall. The yield was about three-fourths of a ton.

The difference in the development of these young roots is no greater than is often found, and I see no satisfactory explanation for the facts. The yield from fields in which the roots are small is just as good as from those in which the roots are larger, without any perceptible difference in the quality of the hay. Some of these seedling roots were almost as large as any of the roots of the plants four years old, growing in an adjacent land. I do not know how soon an alfalfa root may acquire its full growth.

PLATE XI.

It was not possible to get the details of the small roots in photographs of plants whose roots were from 7 to 11½ feet long. We present in this plate the terminal portions of two roots, 7½ feet from the surface, each showing nodules, which appear as round or irregular black spots on the roots.

The extremities of the tap roots, I regret, were broken off.

PLATE XII.

This plate represents the terminal portion of a tap root, 11 feet 9 inches long. There was a fair degree of moisture, but no water at this point. There are a few nodules observable in the plate, but they are few in number and small. This root was in a perfectly healthy condition and was apparently growing vigorously. The spongioles were long, bright, and had every appearance of health and vigor.

PLATE XIII.

This is a mat of roots as it was exposed near the bottom of an excavation by the removal of a part of a layer of coarse gravel, leaving the roots in a cavity. It was due to the looseness and size of the gravel that we were able to obtain the fibrous roots intact. This gravel bed was filled to its upper margin with water, into which these roots penetrated for about 6 inches.

PLATE XIV.

Root nodules are often small and present in large numbers, being strung along the root as small, more or less round or cylindrical bodies, as may be seen to great advantage by digging up a plant of some of the small growing vetches or red clover, although on the latter the nodules are less abundant and larger. They usually occur on the roots of the alfalfa, isolated or grouped together, often forming colonies of considerable size, as shown in the accompanying plate, the largest of which were over 2½ inches across. These groups were of all shapes; some were globular, others flat and irregular in outline. The figures show this plainly. Some of them were broken and shrivelled; others were white and solid. The nodules represented were found at the depths of from 2½ to 5 feet.

PLATES XV., XVI., AND XVII.

The following series of three plates, with six plants, is intended to show the progress of the decaying of the roots at the crown, mentioned elsewhere in this bulletin.

In the first plate one part of the plant has been pulled to the side to show the cavity, which would otherwise have scarcely been seen. In the second one the root has been split down to show a more advanced stage of decay, and also the manner and depth to which it penetrates into the interior of the roots. The rest show different stages in its advance and the manner in which it affects the crown, finally killing it.

PLATE XVIII.

It is stated in the text, under the head of Roots, that it is difficult to explain the fact that alfalfa plants whose roots have been cut by gophers or mice continue to grow. As we believe the long roots to be necessary to the feeding of the plant, the statement is made in this connection that the alfalfa root does not, when eaten off, throw out adventitious roots, which are sufficient to supply so heavy a feeder as this plant is. The following plate is intended to show this and is of plants said to be ten years old. The plants were very much crowded and were all small. They were plowed up on April 29th, and the one with the smallest roots had as large a growth of top as any of the other plants. I cannot judge how long it was since the injury to the roots occurred

Plate L.

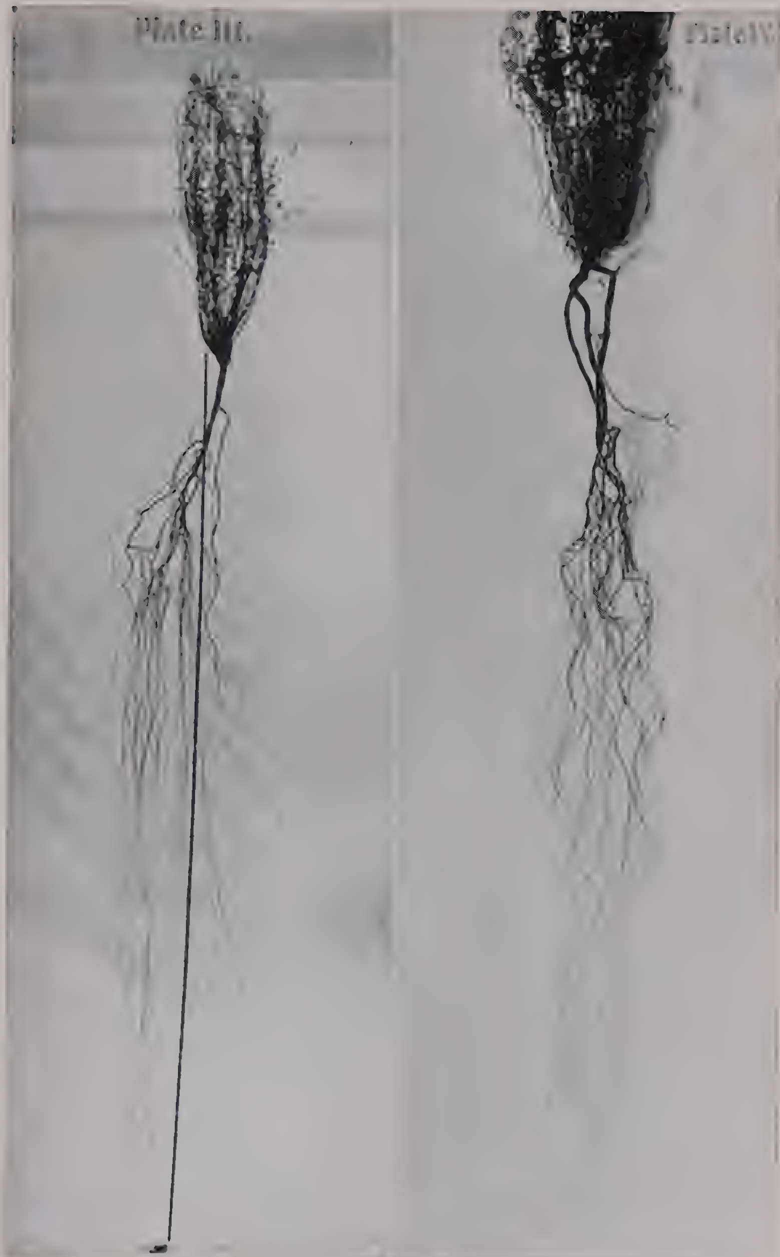
Plate III.
Plate IV.

Plate V.

Plate VI.

Plate VII.

Plate VIII

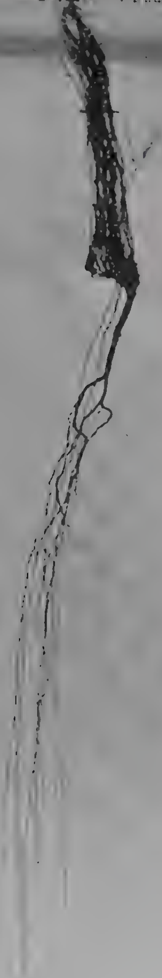

Plate IV.

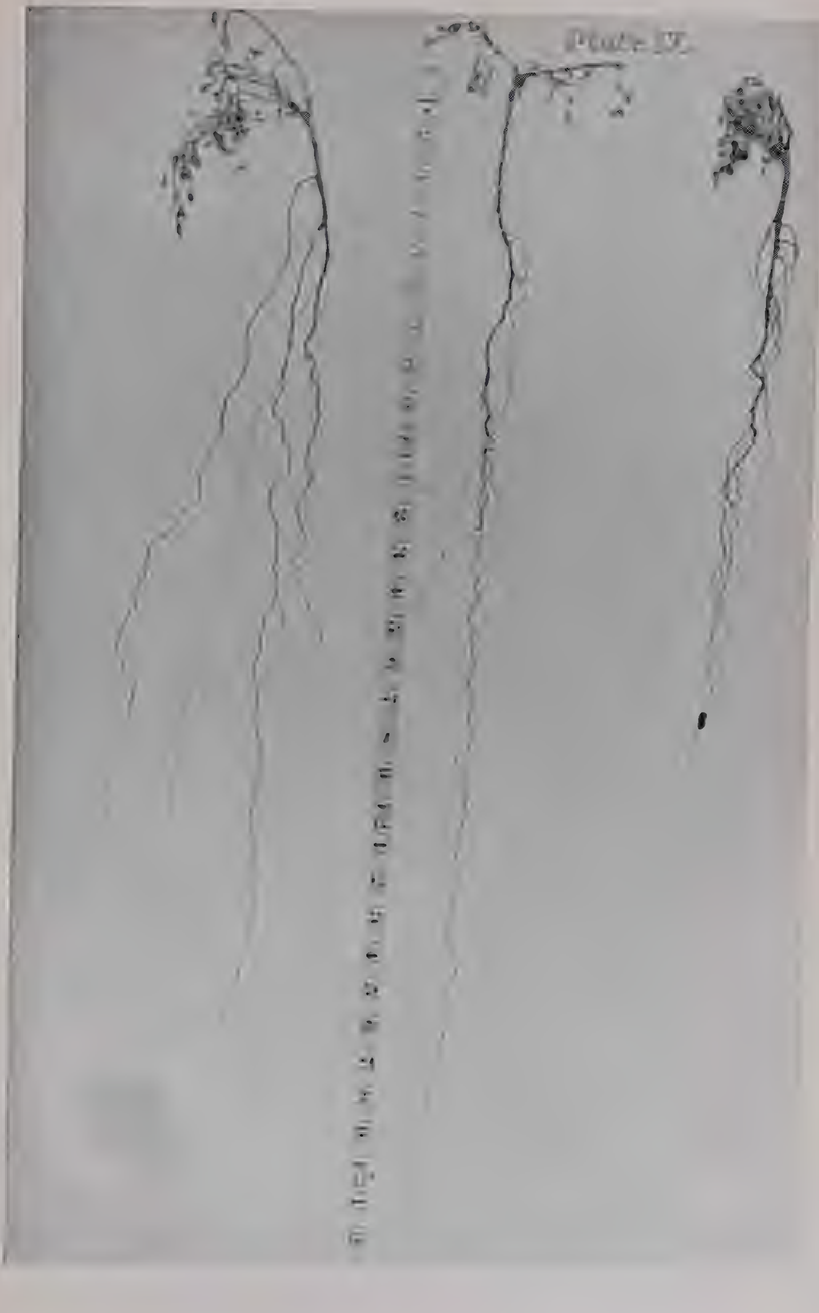

Plate X.

Plate XI.

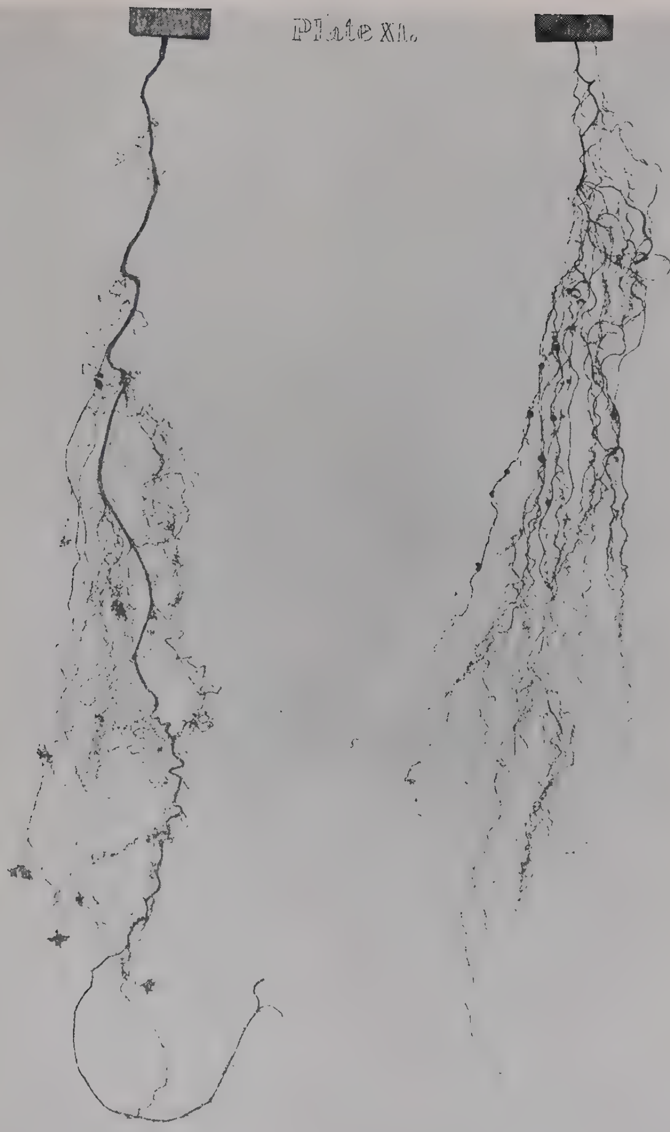

Plate XII.

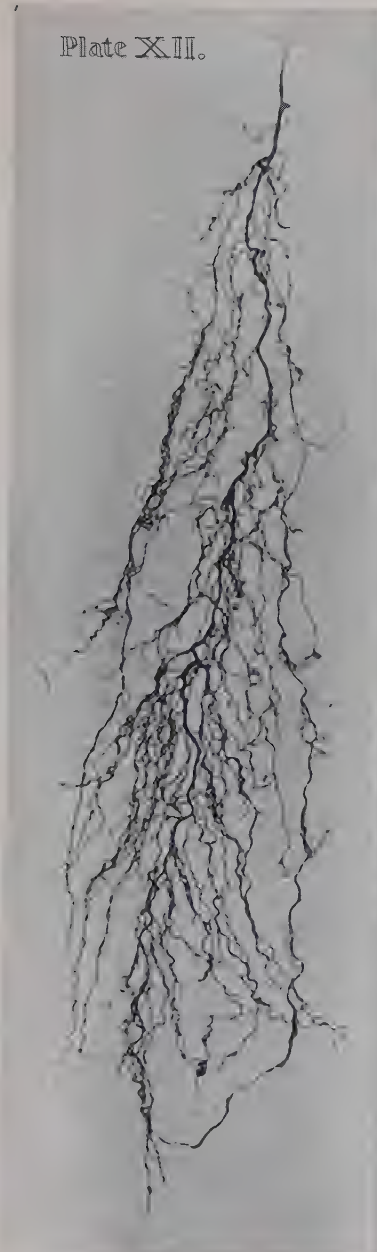

Plate XIII.

Plate XIV

Plate XV

Plate XVI.

Plate XVII.

Plate XVIII

THE STATE AGRICULTURAL COLLEGE.

THE AGRICULTURAL EXPERIMENT STATION.

BULLETIN NO. 36.

SUGAR BEETS.

Approved by the Station Council,

ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

MARCH, 1897.

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DIRECTOR OF THE EXPERIMENT STATION,

Fort Collins, Colorado.

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SUGAR BEETS.

AGRICULTURAL DEPARTMENT.
W. W. COOKE.

The present bulletin is written as an answer to the many letters that come to the Station asking for information about sugar beets. The fact that the number of these letters has largely increased during the past year shows that there is a renewed interest in the subject.

This Station has already sent out four publications on the subject of sugar beets, giving general instructions for their cultivation and detailing the results obtained in the experiments on their growth at the College Farm, on the sub-station at Rocky Ford, and at various places throughout the State. These publications have long been out of print and for this reason it is deemed advisable to repeat here some things that have been before published.

During the five years since the last bulletin on sugar beets was issued, the Station has continued its experiments at the College and many facts have accumulated concerning the adaptability of other parts of the State to sugar beet growing, so that we now have a pretty clear idea of the conditions of the problem for Colorado.

MARKET.

All manufacturers desire first of all to cultivate the home market in order to save transportation charges. He considers himself fortunate who can sell his entire product at the door of his factory. Such is the state of affairs that exists for the manufacturer of sugar in this State. Colorado pays out each year about $500,000 for sugar. This statement is based on the assumption of half a million inhabi-

tants each consuming sixty pounds per year at a cost to the importer of five cents per pound. It would be a great help to the State if this money could be kept at home, as it would be if sugar was made here, since after the factory is once built nearly all expenses are for material and labor produced in the State. To produce the sugar consumed by the inhabitants of Colorado, would require five factories of large size employing two hundred men each, who with their families would represent about four thousand people. It would require the growing of sugar beets on fifteen thousand acres of land and add more than three hundred dollars to the income of each of two thousand farms.

PROFIT.

Are Colorado conditions such as to make the manufacture of beet sugar a profitable industry? The profit of the industry to the factory owner, depends ultimately on the price for which he can sell his product. This market price is at present so largely dependent on political legislation that the question at the head of this paragraph cannot be answered with any certainty.

What can be said is this; that sugar beets will grow as well in Colorado as any where in the world, both as regards their quantity per acre and richness in sugar. Moreover, land suitable for the growth of the beet exists in large bodies now under cultivation in several different parts of the State and this land is near to enormous deposits of coal and lime and but a few miles from the centers of population that will consume the finished product. It follows therefore that if prices are such as to make the business profitable anywhere, then it will pay in Colorado.

GROWTH.

The best possible climate for the growth of the sugar beet is that found in the section of Colorado east of the foothills of the Rocky Mountains and below 5,000 feet altitude. There are many valleys in western Colorado that have a similar climate, but the parks of the State are too cold for the sugar beet to be grown with profit.

The rainfall of Colorado is too small to grow the beet without irrigation, so that its growth will be restricted to the irrigated portions, especially to the valleys of the Arkansas, the Platte, and the Grand.

The soil best adapted to the growth of sugar beets is a rather firm sandy loam; such land as is used in northern Colorado for growing potatoes, and in the Arkansas Valley

is planted to corn. A factory to be profitable must have at its command the beets from at least two thousand acres. There are several places in the Platte Valley where five times that amount is now yearly cropped in potatoes and equally large bodies of land are devoted to corn in the Arkansas Valley.

PLOWING.

A common cause of failure among beginners in sugar beet culture is a lack of thorough preparation of the soil. The sugar beet grows with the entire root below ground, and as this root should be at least twelve inches long, it follows that only the deepest of plowing will make a suitable condition for its growth. The land should be plowed in the fall and subsoiled to a depth of fifteen to eighteen inches. This is especially necessary in an irrigated district, for under irrigation, where the ground is plowed eight inches deep year after year, there is a layer of soil just below the furrow that becomes very compact and so hard that the roots of the sugar beet cannot penetrate it.

If the plowing is done in the fall, nothing more will be needed in the spring but a thorough harrowing just before planting. The harrowing should be continued until the ground is very fine and smooth. If the plowing is done in the spring, it should be delayed until just before planting, so that the weeds that have started will be killed and the beets have a chance to grow before the next crop of weeds appear.

PLANTING.

The planting is done in drills and may be by hand or machine according to the size of the field. The best results are obtained by hand planting, but this is too expensive for a large field. An ordinary garden drill does very good work, but on the large scale some machine drawn by horses will be employed. There are special horse drills made for the planting of sugar beet seed and these are the implements mostly used in the vicinity of factories. For the one who wants to experiment or grow a few acres for stock feed, an ordinary wheat drill makes a very good substitute. In the 8-hoe drill leave open the first, fourth and seventh hole and stop up the rest. This makes the rows of beets twenty-four inches apart, which is none too far for irrigation. Suppose the first hole on the right-hand end of the drill is left open, and seeding is begun at the right-hand end of the field. Then the first time across, the right-hand wheel of the seeder is run close to the edge of

the field. In returning, the left-hand wheel follows the track it made in crossing. In starting across the second time, the right-hand wheel should go sixteen inches from the track it last made. In this way all the drills will be twenty-four inches apart.

The seed should be sown at the rate of about twenty pounds to the acre. This is far more seed than is needed if all grows, and a large part of it will be pulled up when the plants are thinned. But the most serious obstacle to a large crop is the lack of a full stand and the only way to get the ground well covered by plants is to start many more than are needed and thin out the surplus.

The seed should be covered about an inch and a half deep. If seeding happens to be done just after a hard rain, when the ground is thoroughly wet, half an inch deep is sufficient; but usually, in Colorado, the ground is rather dry at time of seeding and unless the seed is covered quite deep, there will not be sufficient moisture to insure germination. The getting a good stand is by far the hardest part of raising sugar beets.

There are a few favored spots in Colorado where irrigation water can be obtained very early in the spring. If then the plowing has not been done in the fall, it may be advisable to irrigate the ground thoroughly before plowing, and thus insure a good supply of moisture in the subsoil.

If, after the seed is sown, there comes on such a dry spell that the seed has to be "irrigated up," the chances of a profitable crop are slight. Even in such a case, there is some chance of success if a small furrow is made six inches from the seed drill and a small head of water allowed to run for quite a while until it has wet the seed by soaking sideways without running over the surface above the seed. This could only be done where the ground is well prepared and has a uniform slope.

Planting may be done any time from the last of March to the middle of June. If planting for a factory, it is advisable that both early and late planting be done, to extend the season for running the factory as long as possible. Where the beets are grown for stock food, the planting will be done at about the time of corn planting. Sugar beets sown the first of May will be ready for harvesting about the first of October.

CULTIVATING.

The first cultivation should take place as soon as possible, that is as soon as enough of the plants show so that the rows can be followed. Many forms of cultivators are on the

market for this particular purpose. Any of the tools used for cultivating onions will do good work on sugar beets. The ordinary one-horse cultivators are often sold with special attachments for working on beets. Whatever implement is used it should merely scratch the surface of the ground, leaving it level and killing the small weeds, without throwing dirt onto the young beets. This cultivation needs to be repeated about once a week until the beets are large enough to shade the ground and conquer the weeds. The ground should be cultivated after each irrigation to throw the dirt back into the irrigating furrow and make a dirt mulch on top that will preserve the moisture. The cultivator should also be run after each rain that the crust formed may be broken up. Ordinarily, it will require about five cultivations to keep the crop in good shape.

IRRIGATION.

The uses of irrigation before plowing and to germinate the seed have already been mentioned. It is advisable to delay the first regular irrigation as long as possible. When it is necessary, it is always given in furrows, care being taken to keep the water off the surface and not let it touch the crowns of the plants. All beet crops in Colorado will require one irrigation, and may need two or three. The cultivator should be run as soon as possible after each irrigation.

The most of the sugar is made by the beet during the last few weeks before it is ripe. To make the highest per cent. of the best sugar it is necessary that at this time the plant should almost cease growing and devote its energies to storing up in the root, as sugar, the nourishment that has already been taken from the ground and elaborated in the leaves. If water is applied at this time by rainfall or by irritation, it induces the plant to keep on growing, making a large weight of crop, but one containing a low amount of sugar. Hence the last irrigation should be given about six weeks before the crop is matured. This will be from the first to the middle of August. In 1895, there was a heavy rain in September at the College Farm, which kept the beets in full growth until frost and gave a crop with much less than the usual amount of sugar. Such rains very seldom occur in Colorado and this fact coupled with the control that the farmer has over his water supply under irrigation makes the growth of a crop with the largest amount of sugar more reliable in this State than in those sections that depend on rainfall to grow the crop.

THINNING.

The thinning should be done when the plant has four leaves. The plants should be thinned so as to leave one plant in a place and the plants from eight to ten inches apart. If the crop is being raised for stock feed and the drills are two feet apart, a plant can be left every six inches. In general there is not much difference in the weight of the crop, at six, eight or ten inches apart, if the soil is rich and there are no missing plants; but the closer the roots are left the less likelihood there is of missing spots and the larger the crop on medium rich soil.

In beets for the manufacture of sugar it is not desired that they grow to a large size. They contain the largest amount of sugar when they weigh about two pounds apiece. They should average under this size rather than over. For stock feed there is less objection to the large beet. By thinning to twelve inches on rich ground it is easy to get beets that weigh five pounds and over, inferior for both sugar and stock food.

The thinning is usually done both by the hand and a hoe. With a narrow, sharp hoe the drill is struck crosswise and the beets cut into hills. The final thinning of these hills to one plant, must be done by hand.

FERTILIZING.

The sugar beet takes from the ground a large amount of plant food. It follows therefore that the land must be liberally manured to keep it fertile. Most of the cultivated land in Colorado, contains at the present time, plenty of fertility to grow several crops without manuring; but at most this is only a temporary condition and sooner or later the farmers of this State will have to follow the customs of their eastern brethren and put as much plant food on the land as the crop carries away.

For the next few years most beet raisers, will obtain fertility for their crops, by growing alfalfa and plowing under the sod. In this case the beet should never follow the alfalfa immediately, but a crop of grain should be grown first. This will rot the alfalfa roots and work the soil into better shape for the sugar beets.

Unless in the case of alkali fields, which will be mentioned later, it is not considered advisable to grow beets more than two years in succession on the same ground. Where the supply of suitable land is not limited, better results will be obtained by raising but one crop, following the next year

with grain, or seeding back to alfalfa. Thus the rotation would be alfalfa three years, wheat one year, beets one year, oats one year with alfalfa seed, and alfalfa for the next three years.

When it becomes necessary to fertilize the ground with barnyard manure, the best crop to follow with is corn. The rotation would then be corn, beets, grain two years, manuring the second year after the grain, and then planting corn again the fifth year. If the stable manure is applied just before the beets, it produces a large crop, but the amount of sugar is small.

VARIETIES.

The varieties mostly used are the Kleinwanzleben and the Vilmorin. The beet sugar factories import this seed and sell it to their patrons at cost. An attempt is now being made in Utah to grow sugar beet seed on a commercial scale.

HARVESTING.

Harvesting for the factory is commenced as soon as the beets are ripe, which stage is known by the change in color of the leaves from green to yellow and at the same time the leaves droop to the ground and many of the outer leaves die and wither. Beets for stock food should be left in the ground as long as possible and gathered just before the ground freezes. In Colorado the harvest will extend from October 15th in the northern part to a month later in the southern and western portions.

Harvesting may be done by a beet puller made for the purpose, which looks much like a sulky plow, but in place of the plow are two strong iron prongs. When the machine is driven lengthwise of the row these prongs dig deep into the ground, one on each side of the beet and loosen it from its bed. It can then be lifted out by hand. A simpler method, and almost as good, is to plow a deep furrow by the side of the row of beets and as close to them as possible without cutting them. They may then be loosened by pushing sideways into the furrow and pulled by hand.

The most tedious and expensive part of the harvesting is the topping. Although machines have been invented for doing this, they have not been successful and the work is still done by hand. A strong heavy knife is used and with a single stroke the leaves are severed from the root. If for sugar, the "neck" of the beet is cut off with the leaves; that is, the part of the beet from which the leaves have grown.

For stock feed, where the beets are to be kept in a root-cellar for several months, this neck is left on the root, the

leaves alone being cut off. Under this condition the beet wilts less and keeps better.

After topping, the beets are thrown into piles, covered over with the leaves and allowed to remain until they are taken to the factory or the root-cellar. If to the root-cellar, the storing should be delayed as long as possible. The danger of heating in the cellar during the fall, is fully as great as that of freezing in the field.

STORING.

The sugar factory will begin running as soon as the earliest beets are ripe. From then until freezing weather sets in, it will work on beets drawn directly from the field. But all factories desire to lengthen the working season as much as possible, to lessen the size of the factory required to work up a given quantity of beets, or with a given sized factory to increase its working capacity. Some precautions have to be taken to preserve the beets from freezing that are to be used the latter part of the season. Long, broad and shallow pits are dug close to the factory into which the beets are thrown, as brought from the field, and then covered with straw and a layer of dirt more or less thick according to the degree of cold to be withstood. It is customary for the factory to supply these pits close to its works, rather than for the farmer to pit the beets in his own field, because it is much more convenient to get at the beets during freezing weather when they are close at hand.

The stock feeder can use the system on his own land near his feeding barn, or he may build a regular root-cellar like those that are found all over Colorado for storing potatoes. The latter way in the course of years is by far the more satisfactory.

COST.

No statement of cost can be given that will not be subject to many changes in different localities. Leaving out of account rent or interest on the value of the land and also any charge for water tax etc., the items of raising an acre of beets will be approximately as follows:

Plowing and harrowing, man and team	10	hours
Seeding, man and team..............	2	"
Cultivating, man and horse..........	20	"
Hoeing, man.........................	135	"
Thinning, man.......................	65	"
Irrigating, man.....................	10	"
Plowing, man and team..............	4	"
Pulling, man........................	20	"
Topping, man........................	80	"

Hauling will always be an item of cost, but varies from eight hours for man and team, to thirty hours according to distance to be hauled and facilities for hauling.

The time and expense for planting and cultivating the crop, will be about the same whether the yield is large or small. The expense of harvesting has been figured on the basis of twelve tons to the acre and will rise or fall according as the crop is greater or less.

Under the varying prices of labor, the ease with which the land can be worked, and the size of the crop, the cost of raising and marketing an acre of sugar beets has varied at different places in the United States from $30 to $45, and the cost per ton of beets from $2 to $4.

Beets are usually paid for according to their richness, the prices varying from $4 to $5 per ton and the returns per acre will average not far from $50. About eleven tons of sugar beets per acre at $4.50 per ton is a fair average crop, with a possibility of more than twenty tons at $5 per ton. As compared with $10 for the crop from the same land put into alfalfa, or $12 for the wheat it would raise, this return seems rather large, but of course there is a much larger amount of labor required to produce this return.

FEEDING VALUE.

Sugar beets have a high value for stock feed. They belong to the class of concentrated feeds in spite of the large amount of water they contain and are to be compared as a feed with grain rather than hay.

It is probable that the dry matter of beets has about the same value, pound for pound as the dry digestible matter in grain. On that basis, a pound of grain would have as much feeding value as four and one-half or five pounds of beets.

Sugar beets have been fed to stock at the College with very good results except where fed to steers. When the feeding is done out doors in cold weather, they seem to be too watery for profitable feeding to steers. They are excellent feed for milch cows and will take the place of grain for fattening lambs during the first half of the feeding period. It is advisable not to feed them during the last six weeks before marketing, giving grain at that time so that the flesh and fat may harden for shipment. Stock sheep and breeding ewes do well on beets all winter. They can even form profitably a portion of the food of breeding sows.

FEEDING VALUE OF LEAVES AND TOPS.

For every one hundred pounds of beets harvested there will be from fifty to sixty pounds of tops. These tops have

a high feeding value. They are worth almost as much pound for pound as the beets themselves.

The tops are good feed for all classes of farm animals. They may be fed at once as soon as harvested or put in a silo and fed through the winter. The past two years, on the College Farm, there has been stock enough to eat them as fast as gathered. They have been fed to breeding sheep and to cows, being hauled from the field and fed in racks. Some beet growers wait until the crop is all harvested and then turn the stock into the field to eat up the tops and leaves. This saves some labor but is wasteful of fodder.

CHEMICAL DEPARTMENT.

WILLIAM P. HEADDEN.

The following pages contain the analytical results obtained in the laboratory of this Station up to the present time. The greater part of them have already appeared in Bulletins Nos. 7, 11, 14, and 21. The data concerning the condition of soil and cultivation, under which the beets were grown, are not given in satisfactory fullness in all cases, but in others it leaves little to be desired.

The record of analyses of all samples analyzed is interesting and profitable to the inexperienced beet grower, as showing the extent to which the sugar content of the beet is dependent upon the cultivation it receives as well as upon the character of the soil in which it is grown.

It is evident, from our records, that a great many persons have furnished the department samples but once, and that was the only attempt that they had made in sugar beet raising. A complete record of the work done in the laboratory would contain many samples of which this would be true and which would give a wholly erroneous impression of the facts as to the quality of beets grown in the various parts of the State under proper cultivation.

In 1888, the Station experimented with four varieties of beets: Excelsior, Lane's Imperial, Vilmorin, and Imperial Improved, with the following results:

Varieties.	Per cent. sugar.	Tons beets per acre.	Pounds sugar per acre.
Excelsior	9.47	29.04	5,517.60
Lane's Imperial	12.08	30.45	7,318.00
Vilmorin	11.39	25.09	5,695.48
Imperial Improved	8.83	24.15	4,250.40

The number of analyses seem to have been small, but the samples were representative of the four lots grown; and while the percentage of sugar varied considerably the results were considered satisfactory, indicating that beets of good quality can be grown in Colorado, and that the yield is large.

The study was continued the following year (1889) on a somewhat different line, i. e., to determine the effect of different soils upon the ash constituents and percentage of sugar in the beets; also to determine the feeding value of the tops and the relation of the weight of the tops to the sugar content of the beet. The second object of this experiment was defeated by an early frost which killed the tops.

A further object was to study the distribution of the sugar in transverse sections of the beets and the relation of the specific gravity of the juice to the sugar content.

In order to establish the first point, the relation of the ash and its constituents to the soil in which the beets grew, the ashes of two varieties of beets, one lot of each, grown upon rich and poor soil respectively, were subjected to analysis. Just what is meant by poor soil and rich soil is not definitely stated and so far as I can learn, the soils were not analyzed. In one paragraph the terms fertilized and unfertilized are used as explanatory of rich and poor, but the rest of the record seems to justify the inference that the term poor, is used in its ordinary signification, and rich to indicate a productive condition of the soil, but not a condition produced by the application of manure or other fertilizer immediately prior to the growing of this crop.

The following data show that the Silesian appropriated nearly one-fifth more mineral constituents and the Imperial over one-half more from the rich than from the poor soil. The Silesian, grown on poor soil, contained 1.08 per cent., but grown on rich soil, it showed 1.28 per cent. And the Imperial, grown under similar conditions, contained 0.801 per cent., and 1.234 per cent., respectively.

There is a difference both in the amount of ash contained in the beets and in its composition, according to the quality of the soil on which the beets are grown. The percentages of phosphoric acid and lime are higher in the case of beets grown on poor soils, but the percentage of potash is higher in those grown on rich soils.

The experiment was not conclusive in regard to the effect of the two soils upon the percentage of sugar. The

Silesian grown on poor soil contained 9.66 per cent. sugar; the same variety grown on rich soil contained 10.47 per cent., while the Imperial, grown on poor soil, contained 10.44 per cent., and grown on rich soil, contained only 9.07 per cent. The difference in either case is too small, especially as it is based on so small a number of analyses, to be conclusive.

The amount of sugar in successive transverse sections of these varieties was also made, the sections being taken one inch thick, beginning to number at the top. The result of this examination was that the first section contained less sugar than any other section, except in one instance, and always from two to over four per cent. less than the maximum in any one section which was found in the tip of the beet. The increased amount of sugar was, with one exception, quite marked in the second section of the beet; in the succeeding sections it was much less and quite regular. In the case of the Silesian grown on rich soil the difference in the quantity of sugar in the first and second sections amounted to 1.21 per cent.; in the second and third to 0.7 per cent.; in the third and fourth 0.29 per cent.; in the fourth and fifth 0.29 per cent.; in the fifth and sixth 0.04 per cent.; and in the sixth and seventh 0.25 per cent. The loss on dressing was between two and three per cent., and was about the same whether the beets were grown in rich or poor soil.

The feeding value of the beets, as influenced by the soil, was also studied. The study of the tops was prevented by an early frost, but the analyses of the roots, as given in Bulletin No. 11, are as follows:

	Water.	Crude ash.	Fat.	Crude protein.	Crude fiber.	Nitrogen free extract.
Silesian, poor soil	87.17	1.08	0.24	0.93	0.83	9.75
Silesian, rich soil	86.31	1.28	0.27	1.77	0.68	9.69
Imperial, poor soil	87.88	0.80	0.14	0.81	0.59	9.78
Imperial, rich soil	89.80	1.23	0.18	1.44	0.44	6 91
Vilmorin	88.69	1.13	0.18	1.16	0.62	8.22
*Average analysis of sugar beets	86.50	0.90	0.10	1.80	0.90	9.80

*As given by Jenkins and Winton, Exp. Sta. Bul. 11.

The same is true of the results recorded in this series of analyses as of the sugar determinations, i. e., they have a general value as they show the beets to have been about

equal to the average sugar beet, so far as their feeding value was concerned, but the results are not positive enough nor based on a sufficiently extended series of experiments to show conclusively that the value of the roots for feeding purposes was materially affected by the nature of the different soils. It may be stated in this connection, that it is known that the beet is very sensitive to the influence of fertilizers and the cultivation it receives, particularly in regard to the purity of the juice or ratio of the sugar to the total solids.

Large beets are frequently received, being sent under the mistaken idea that the larger the beet the higher the percentage of sugar, which is not the case. The following table, reproduced from Bulletin No. 14, illustrates this, though the weight of the largest beet is much less than that of many samples sent us for analysis. The samples were selected with reference to their size as shown by the following table:

	Size.	Weight.	Loss on dressing.	Per cent. sugar.
Bulteau Desprez	Large.	1,245	170	12.83
" "	Medium.	285	20	14.10
" "	Small.	43	3	15.97
Kleinwanzleben	Large.	1,015	135	14.12
" "	Medium.	240	20	14.18
" "	Small.	42	2	17.11
Dippe's Vilmorin	Large.	860	70	14.37
" "	Medium.	280	35	14.84
" "	Small.	42	2	16.66
Bulteau Desprez, No. 2	Large.	980	110	14.26
" " "	Medium.	375	30	15.68
" " "	Small.	89	5	16.09
Simon Le Grande	Large.	1,150	150	12.17
" "	Medium.	130	10	12.88
" "	Small.	43	3	13.52
Florimond	Large.	1,310	170	12.99
"	Medium.	175	10	15.54
"	Small.	30	3	17.05

The size of the beet can be controlled by letting it stand closer in the row and its quality further improved by careful attention to cultivation and fertilizing.

Samples of the following varieties were sent to the Department of Agriculture, at Washington, for analysis and Dr. Wiley reports the results to Prof. Crandall, October 2, 1890, as follows:

	Per cent sugar.
Kleinwanzleben	10.11
Simon Le Grande	11.15
Florimond	15.39
Bulteau Desprez No. 1	15.20
Bulteau Desprez No. 2	14.75
Vilmorin	12.92

Samples were also sent to Grand Island, Neb., and their chemist reports, under date of Nov. 12, 1890, the following:

	Per cent. sugar.
Excelsior sugar	7.40
Improved Imperial	8.20
Bulteau Desprez	14.40
Dippe's Vilmorin	14.70
Kleinwanzleben	13.50
Florimond	13.20
Simon Le Grande	13.50

Taking the average of the analyses of the varieties made in this laboratory, we have:

	Per cent. sugar.
Bulteau Desprez No. 2	15.03
Bulteau Desprez No. 1	15.88
Kleinwanzleben	15.64
Dippe's Vilmorin	15.75
Florimond	16.30

The preceding samples were grown in a highly cultivated soil under the supervision of the Horticultural Department. The total solids do not seem to have been determined. Analyses were made of the following samples from various parts of the State, and also others which, being unaccompanied by any history, are omitted:

Name.	Where and by whom grown.	Per cent. Sugar.
Colorado Imperial	A. R. Black, Lamar, Colo.	8.02
California Sugar	" " "	13.03
Colored Vilmorin Desprez	" " "	11.26
Imported Florimond	" " "	8.45
Kleinwanzleben	" " "	11.04
Vilmorin	Stimson, Neb.	10.38
Simon LeGrande's White Imperial	San Luis Valley Stat'n, Monte Vista, Colo.	15.59
Bulteau Desprez	" " "	11.82
Vilmorin	" " "	14.14
Vilmorin Desprez	" " "	12.25
Kleinwanzleben	" " "	13.35
Red Top	Arkansas Valley Stat'n, Rocky Ford, Colo	11.84
Simon LeGrande	" " "	13.28
Dippe's Vilmorin	" " "	14.09
Florimond Desprez	" " "	14.72
Bulteau Desprez	" " "	12.89
Kleinwanzleben	" " "	13.66
Improved Imperial	College Garden, Fort Collins, Colo.	8.70
Imperial	" " "	9.75
Excelsior	" " "	6.95
Kleinwanzleben	" " "	12.57
Bulteau Desprez	" " "	13.37
Florimond Desprez	" " "	12.90
Dippe's Vilmorin	" " "	14.20
Bulteau Desprez	" " "	14.18
Simon LeGrande	" " "	11.38
Kleinwanzleben	" " "	11.11
Bulteau Desprez	" " "	10.97
Florimond	" " "	9.82
Dippe's Vilmorin	" " "	12.74
Bulteau Desprez	" " "	11.12
Simon LeGrande	" " "	9.26
Imperial	Chas. Green, Del Norte, Colo.	14.08
Imperial	A. S. Halsted, Del Norte, Colo.	14.76
Lane's Imperial	Chas. Schielman, La Junta, Colo.	11.80
Lane's Imperial	....	15.68
Imperial	....	15.00
Vilmorin	Denver, Colo.	18.00
Bulteau Desprez	" "	15.00

Name.	Where and by whom grown.	Per cent. Sugar.
Vilmorin	Denver, Colo.	16.00
Vilmorin	" "	16.00
Bulteau, No. 2	" "	16.00
Vilmorin, No. 8	" "	15.00
Improved Imperial	College Farm, Fort Collins, Colo.	8.80
French Variety	" " "	10.20
Vilmorin No. 1	Arkansas Valley Station, Rocky Ford.	6.00
Vilmorin, No. 2	" " "	9.20
Vilmorin, No. 3	" " "	10.75
Vilmorin, No. 4	" " "	8.50
Lane's Improved Imperial	College Farm, Fort Collins, Colo.	8.95
Vilmorin Improved	" " "	9.68
Dippe's Vilmorin	Arkansas Valley Station, Rocky Ford.	15.17
Dippe's Vilmorin	" " "	15 35
Dippe's Vilmorin	" " "	15.37
Dippe's Vilmorin	" " "	11.48
Vilmorin Improved	College Farm, Fort Collins, Colo.	8.00
Vilmorin Improved	" " "	11.15
Vilmorin Improved	" " "	13.69
Lane's Imperial	" " "	8.95
Improved Imperial	" " "	8.83
*Name not given	" " "	10.21
Name not given	Divide Experiment Sta. Monument, Colo.	9.35
Kleinwanzleben	" " "	7.95
Kleinwanzleben	" " "	9.67
Dippe's Vilmorin	Arkansas Valley Station, Rocky Ford.	15.17
Dippe's Vilm rin	" " "	15.35
Dippe's Vilmorin	" " "	15.35
Dippe's Vilmorin	" " "	11.48

*This set of farm samples is accompanied by a note to the effect that they did not have water enough, but there is no further explanation.

The Department of Horticulture sent to the laboratory four samples, grown at different distances in the rows, to test the effect upon the percentage of sugar in the beets. The results are as follows:

Variety.	Inches apart in row.	Per cent. sugar.
Vilmorin Improved	3	13.60
Vilmorin Improved	3	13.50
Vilmorin Improved	6	9.00
Vilmorin Improved	6	11.00

The result is clearly in favor of a thick stand. Neither the distance between the rows nor the weights of the beets are given.

Seed beets, to the number of 110 of the Vilmorin varieties, were analyzed; the results may be summarized as follows: The percentage of sugar ranged from 7 to 17, and it is noted that the beets were in bad condition. Seven of the 110 beets contained less than 10 per cent. of sugar and sixteen of them contained upwards of 14 per cent.

The following samples are accompanied by a statement of the number of irrigations with which they were grown. The rainfall at Fort Collins, from May to October, inclusive, was 8.8 inches; at Rocky Ford, 8.26 inches, and at the San Luis Valley station, 4.58 inches.

Name.	Where grown.	Times irrigated	Per cent. sugar.	Coefficient of purity.
Vilmorin, No. 1	Arkansas Valley Station.	..	6.00	....
Vilmorin, No. 2	" " "	1	9.00	....
Vilmorin, No. 3	" " "	..	10.75	....
Vilmorin, No. 4	" " "	..	8.50	....
Vilmorin,	College Farm.	.	14.75	81
Vilmorin	"	..	15.25	82
Vilmorin Improved	"	..	13.69	....
Vilmorin Improved	"	..	11.15	....
Kleinwanzleben	Divide Station.	..	13.00	....
Kleinwanzleben	"	..	13.70	....
Vilmorin Improved	San Luis Valley.	..	13.50	....
Vilmorin	Arkansas Valley Station.	..	21.00	....
No name given	" " "	..	14.00	....
Dippe's Vilmorin	" " "	1	15.17	....
Dippe's Vilmorin	" " "	2	15.35	....
Dippe's Vilmorin	" " "	3	15.37	....
Dippe's Vilmorin	" " "	4	11.48	....

Name.	Where grown.	Times irrigated.	Per cent. sugar.	Coefficient of purity.
Vilmorin Improved	San Luis Valley Station.	3	13.50	....
Vilmorin No. 4	College Farm.	3	14.00	....
Vilmorin No. 5	"	3	14.00	....
Vilmorin	"	..	16.50	....
Kleinwanzleben	Bellvue, Colo.	seepage	8.00	....
Vilmorin Improved	"	seepage	9.00	....
Kleinwanzleben	Arkansas Valley Station.	5	12.30	92.8
Vilmorin Brabant	" " "	5	8.80	80.0
Lane's Imperial	" " "	5	8.00	80.0
Dippe's Improved	" " "	5	8.00	72.0
Dippe's Improved rich sugar	" " "	5	7.70	55.0
Vilmorin	" " "	5	12.70	90.0
Vilmorin	" " "	5	13.43	67.0
Kleinwanzleben	" " "	5	8.80	63.0
Kleinwanzleben	" " "	1	10.00	55.5
Dippe's Improved rich sugar	" " "	1	10.00	71.4
Vilmorin Brabant Imperial	" " "	1	10.10	71.4
Vilmorin	" " "	1	11.50	71.8
Vilmorin No. 7	" " "	1	10.50	55.2
Lane's Imperial	" " "	1	10.70	56.3
Dippe's Improved White Imperial	" " "	1	5.70	38.0
Vilmorin	College Farm.	2	12.70	84.6
Red Skinned	"	2	15.00	88.2
Silesian	"	2	13.30	88.6
Lane's Improved	"	2	11.70	83.5
Neise Improved	"	2	16.50	91.6
Vilmorin White	"	2	15.30	90.0
Vilmorin Improved	"	2	13.50	84.3
Dippe's Kleinwanzleben	Fort Collins.	2	11.10	70.0
Vilmorin	"	2	10.30	70.0
Bulteau Desprez	"	2	11.70	73.1
Vilmorin rich sugar	"	2	11.17	65.7
Kleinwanzleben	La Junta.	8	10.80	72.0
Vilmorin Improved	La Porte.	seepage	11.00	57.5
Kleinwanzleben	"	seepage	12.50	83.3
Vilmorin	Timnath.	2	10.50	87.5
Kleinwanzleben	Brighton.	2	15.54	91.4
Vilmorin	Loveland.	4	11.00	73.3
Kleinwanzleben	"	4	12.75	79.7

Name.	Where grown.	Times irrigated.	Per cent. sugar.	Coefficient of purity.
Vilmorin Imperial..................	San Luis Valley.	..	13.55	85.3
Vilmorin Imperial..	" " "	..	14.08	87.1
Vilmorin...........................	College Farm.	..	15.40	79.0
Vilmorin........................	"	..	14.78	79.7
Vilmorin...........................	"	..	16.63	80.0
Silesian	"	..	14.42	83.9
Red Skinned........................	"	..	15.16	81.4
Vilmorin Imperial..................	"	..	16.13	84.5
Lane's Imperial....................	"	..	16.50	86.9
Vilmorin White.....................	"	..	18.59	89.0
Neise Imperial.....................	"	..	19.37	90.6
Vilmorin Imperial..................	"	..	16.52	86.1
Vilmorin...........................	"	..	18.90	84.3

The last thirteen analyses were made at the Department of Agriculture, Washington, D.C.

The record is not complete enough to justify more than the general statement that an excess of water is as detrimental to the yield of sugar as a lack of water. The record, so far as it goes, shows that those beets which received two and three irrigations contain the highest average percentage of sugar, while those which received one and five, stand quite close to each other, and are much lower than those which received two and three irrigations. There are some pronounced exceptions to this, particularly in some instances in which the plants received five irrigations. Out of eight samples, furnished by the Arkansas Valley Station, each plat having received five irrigations, five of them showed less than 9 per cent. of sugar, and none of them reached 14 per cent. of sugar; whereas, the samples from this Station, grown with fewer irrigations, show from 12 to 21 per cent. With one irrigation only, the percentage of sugar varies between 6 and 11 per cent., with one exception, which reaches 15.17 per cent.

The average percentage of sugar in beets grown on the College Farm, and analyzed in this laboratory, is 12.8 per cent.; but in 1893, we had heavy rains during the latter part of September and in October, immediately prior to harvesting the beets. The average percentage of sugar, as determined in seventeen samples, was 10.24 per cent., with a coefficient of purity ranging from 44.36 to 76.30. In one only did the coefficient of purity reach 81.13.

The alkalized portions of our land are wet and the beets grown on the College Farm in such soils have contained but little sugar. The Vilmorin made the best showing with 10.60 per cent. sugar. Whether this is due to the alkali or the water, matters not so far as the value of the beets is concerned.

The only attempt to raise sugar beets in the more elevated portions of the State, which has come to my knowledge, was made in the counties of Garfield, Eagle, and Pitkin, during the past season. The individual beets were mostly large, and no history of the soil in which they grew, or the cultivation which they received, was furnished with the samples. But it was the first experience which any of the growers had had in this line and they had apparently chosen the richest soil in which to make their experiment. Still 53 per cent. of the samples contained from 10 to 15 per cent. of sugar. The results of the experiment show that these counties can produce beets suitable for the manufacture of sugar, perhaps not to the same extent or at so fair a profit as our lower-lying districts, but still with great advantage to themselves.

The State Agricultural College

THE AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 37

TECHNICAL SERIES No. 2

The Birds of Colorado

BY

W. W. COOKE

APPROVED BY THE STATION COUNCIL

ALSTON ELLIS, President

FORT COLLINS, COLORADO

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THE BIRDS OF COLORADO.

BY W. W. COOKE.

The following paper is designed to set forth our present knowledge of the distribution and migration of Colorado birds. There is also included a bibliography of the subject and an historical review of the progress of ornithological investigation in this State.

The total number of species and varieties of birds known to occur in Colorado is 360, of which 228 are known to breed. This is a larger number of species than has been taken in any state east of the Mississippi and is exceeded by only one state of the Union, that is by Nebraska with nearly four hundred species.

The reason for this great variety of bird life is found in the geographical position of the State and the physical characteristics of its surface.

From the Atlantic Ocean to western Iowa but slight changes occur in the avi-fauna. But with the decreased rainfall and the increase in altitude from there westward, a great number of new forms appear. The greatest change is at the eastern foothills of the Rocky Mountains, which is the natural dividing line between the eastern and middle provinces of the United States. But while many of the western forms extend as stragglers eastward into Kansas and Nebraska and especially into the Black Hills of South Dakota and northwestern Nebraska, a large number of eastern forms do not pass west of the semi-arid region of twenty inches of annual rainfall and are not found in Colorado. It is due to this fact that Nebraska exceeds Colorado in the number of species taken in the State. All of the eastern species reach Nebraska and nearly all the western forms extend into northwestern Nebraska. This is strikingly shown in the case of the Warblers. Nebraska has more than twenty Warblers that do not occur in Colorado, while Colorado has less than five that are not found in Nebraska.

The avi-fauna of Colorado is reinforced by species that belong more properly to the regions on all sides of it. The basis may be considered as the species that range over the whole of the United States and those that are most abundant

in the middle west. As additions to these, there come to the State from the east such distinctively eastern species as the Bobolink, Phœbe, Blue Bird, and Baltimore Oriole; from the west the Dwarf Hermit Thrush, Grace's Warbler, Golden-crowned Sparrow, and the Black Swift; from the north Holbœll's Grebe, Arctic Tern, Harlequin Duck, and Barrow's Golden-eye; while something over twenty truly southern species have been taken as stragglers in southern Colorado.

Of accidental visitants we have our share. Three varieties of Surf Ducks have wandered to Colorado; a specimen of the English *Saxicola œnanthe* was taken near Boulder, a Bendire's Thrasher at Colorado Springs, an Olivaceous Flycatcher at Fort Lyon, a White-winged Dove in Jefferson County, a White Ibis at Denver, a Roseate Spoonbill at Silverton, and most wonderful of all, a Scarlet Ibis near Pueblo.

The broken character of the surface of Colorado offers inducements for birds of all kinds. The eastern third of the State is a vast plain, rising from an altitude of 3,500 feet at its eastern edge to nearly 6,000 feet where it joins the foothills of the Rockies. This whole region is treeless, except a narrow fringe along the streams. Innumerable throngs of birds sweep across it during migration, especially water fowl and waders, but its attractions are too few to induce many to remain through the summer.

The center of the State is occupied by the Continental Divide. Range on range attaining a height of over 14,000 feet offers favorable conditions for even boreal species. The great mountain parks lie in this section, and at an altitude of 8,000 feet mark the limit of height reached by the great bulk of the species.

The western third of Colorado presents a wilderness of rolling hills from 5,000 to 8,000 feet in altitude, covered with a few trees and a very scanty vegetation. Bird life is present in small numbers but great variety and partakes largely of western characteristics.

The temperature of Colorado is much below that of corresponding latitudes in the Mississippi Valley. On the plains the average for the year is not far from 52° F., with extremes more marked and changes more sudden than in moister climates. At 7,000 feet among the mountains the average temperature is five degrees lower, and at 9,000 feet only a little colder.

Timber line is about 11,500 feet in Colorado and with an average temperature of two degrees below freezing is yet the home of some birds for the entire year, while during the short summer many species find here congenial nesting sites.

The rainfall on the plains is about fourteen inches per year, increasing to twenty inches at 8,000 feet in northern Colorado, but in the southern scarcely reaching that amount until nearly to timber line. This scarcity of rain has a direct influence on the vegetation and through that on the distribution of the birds. With the exception of a few species of sparrows, almost all the bird life of the State is confined to the vicinity of water or high enough on the mountains to reach timber.

The records given in this bulletin are based first of all on the printed matter that has appeared dealing with the birds of Colorado. This mass of material has been supplemented by much manuscript matter, and by the personal observations of the author during a four years' residence in the State.

There is no State in the Union that offers a more difficult field for thorough work, and a recapitulation of our present knowledge only serves to bring out more clearly the many points on which further information is needed.

The only claim for completeness made by the present list is that it is complete so far as work done up to this time is concerned. Experience in this State as well as in others teaches that additions will be made for many years to come. These will not be confined to any one part of the State nor to any particular class of birds. In addition to accidental visitants, it may be confidently expected that several more eastern species will be found to follow up the Arkansas and the Platte Rivers, and a still greater number of western species up the valley of the Grand into western Colorado.

Though much ornithological work has been done in Colorado, many parts of the State have never yet been visited by an ornithologist. The region along the eastern base of the foothills at the juncture of mountain and plain has been quite thoroughly studied. Fully four-fifths of all the records of Colorado pertain to this narrow strip, thirty miles wide and one hundred and fifty miles in length. As this constitutes less than one-twentieth of the area of the State, it can be seen how little attention has been paid to much of Colorado. In this strip, Beckham, Nash and Lowe have worked at Pueblo; Aiken at Pueblo, Cañon City and Colorado Springs; Allen at Colorado Springs; Henshaw, Anthony and H. G. Smith at Denver; Trippe at Idaho Springs; Gale at Gold Hill; W. G. Smith and Osburn at Loveland; Breninger at Fort Collins, and Dille at Greeley. In most cases this work has been continuous through the year, and has resulted in a pretty thorough knowledge of the main features of the ornithology of this region. About a dozen other ornithologists have given us results of short visits to various places in this belt.

Eastward lie the great plains, stretching 150 miles from Pueblo to the Kansas line and crossing the whole breadth of Colorado. Here is an extent of country four times as large as the State of Massachusetts, and in this whole region but two ornithologists have ever worked. Capt. P. M. Thorne was at Fort Lyon, on the Arkansas, and Mr. H. G. Hoskins at Burlington and vicinity, in Kit Carson County. There are fourteen counties in eastern Colorado that have not a single printed bird record to their credit.

The great parks of Colorado have received but little more attention. Coues crossed North Park; Stevenson, Middle Park, and Allen, South Park, and took hurried glimpses at the bird life. San Luis Park has fared somewhat better, thanks to the labors of Henshaw and Aiken. Stone spent several months between South Park and San Luis Park, in the vicinity of Hancock. In southwestern Colorado, Drew in San Juan County, and Morrison in La Plata County, have given us valuable notes on the birds of the higher portions of the region. The whole of northwestern Colorado remains unexplored. What a field for the ornithologist! As large as the whole of New England outside of Maine, and containing the whole valley of the Grand River and its tributaries, it will reward the zealous seeker with many Pacific forms not now known to Colorado. No other part of the State will probably show so large a return as the region around Grand Junction. Other specially favorable localities for new developments are the lower waters of the tributaries of the San Juan River in southwestern Colorado, the region around Trinidad in south central Colorado, the Arkansas River near the Kansas line, and especially the Cimarron River of southeastern Colorado and the Platte River near Julesburg in northeastern Colorado.

For increased knowledge of distribution with regard to altitude, and for range during the breeding season, so little is known compared with what remains to be discovered that any part of the mountain region of Colorado offers an inviting field to the ornithologist.

In addition to the mass of published data accessible to all, the present writer has received valuable assistance from many manuscript notes, and he wishes here to express his thanks to the correspondents who have put so much time, labor and care into their preparation. Much information on special points has been obtained in answer to direct inquiries and also the following lists have been received:

A. W. Anthony. List of 226 species known by him to have been taken in Colorado.

W. H. Bergtold. Notes on 20 species seen by him in Routt County and near Denver.

G. F. Breninger. List of 257 species known by him to have been taken in Larimer County.

R. A. Campbell. List of 40 species noted near Boulder.

E. B. Darnell. Notes on 68 species found in Routt County.

H. G. Hoskins. Notes on 58 species seen near Burlington, and dates of migration for four years.

Mortimer Jesurn, M. D. List, with annotations, of 161 species taken on the Platte River 150 miles north of Cheyenne.

W. P. Lowe. List of 188 species found at Pueblo and in the Wet Mountains, distinguishing the breeders.

Chas. F. Morrison. List of 332 species known to occur in Colorado, of which 152 are marked as breeding in the State.

Wm. Osburn. Annotated list of 254 species identified by himself and Wm. G. Smith in the vicinity of Loveland.

Capt. P. M. Thorne. Annotated list of 160 species shot by him during five years residence at Fort Lyon. Especially valuable, because nearly all the specimens have been identified by Mr. Brewster and are now in the Field Museum in Chicago.

One of the hardest things to determine in making out a state list, is what shall constitute a valid record and entitle the bird to a place in the list. The present writer has endeavored to take a middle course between including everything that seemed to have a fair claim for admission and excluding everything to whose record attached any suspicion. With all species at all doubtful the full record has been given, so that future students may judge for themselves whether the species is entitled to entry. This course has been taken owing to the small amount of work that has as yet been done on Colorado ornithology. Some readers will undoubtedly believe that the records of some of the species here given need confirmation and should have been omitted. On the other hand the author can say that he has in his possession the records of *forty-two* species that have been ascribed to Colorado. Many of these, in fact the larger part of them, he believes to occur in the State, yet they have been excluded from this list, pending further information.

CLASSIFICATION OF COLORADO BIRDS.

1. Residents; species found in the State at all times of the year regardless of the season.

Merganser americanus.
Lophodytes cucullatus.
Anas boschas.
Dafila acuta.
Clangula islandica.
Histrionicus histrionicus.
Colinus virginianus.
Callipepla californica.
Callipepla gambeli.
Dendragapus obscurus.
Bonasa umbellus umbelloides.
Lagopus leucurus.
Pediocætes phasianellus campestris.
Centrocercus urophasianus.
Meleagris gallopavo.
Meleagris gallopavo mexicana.
Circus hudsonius.
Accipiter velox.
Accipiter cooperi.
Accipiter atricapillus.
Buteo borealis kriderii.
Buteo borealis calurus.
Buteo swainsoni.
Archibuteo ferrugineus.
Aquila chrysaëtos.
Haliæetus leucocephalus.
Falco mexicanus.
Falco peregrinus anatum.
Falco sparverius.
Strix pratincola.
Asio wilsonianus.
Asio accipitrinus.
Syrnium occidentale.
Nyctala acadica.
Megascops asio.
Megascops asio maxwelliæ.
Megascops asio aikeni.
Megascops flammeola.
Bubo virginianus subarcticus.
Speotyto cunicularia hypogæa.
Glaucidium gnoma.
Conurus carolinensis (formerly)
Geococcyx californianus.
Ceryle alcyon.
Dryobates villosus hyloscopus.
Dryobates pubescens homorus.
Dryobates scalaris bairdi.
Picoides americanus dorsalis.
Ceophlœus pileatus.
Melanerpes torquatus.
Colaptes cafer.
Otocoris alpestris arenicola.
Pica pica hudsonica.
Cyanocitta stelleri macrolopha.
Aphelocoma woodhousei.
Perisoreus canadensis capitalis.
Corvus corax sinuatus.
Corvus cryptoleucus.
Corvus americanus.
Nucifraga columbiana.
Cyanocephalus cyanocephalus.
Pinicola enucleator.
Carpodacus cassini.
Carpodacus mexicanus frontalis.
Loxia curvirostra stricklandi.
Leucosticte australis.
Spinus tristis.
Spinus pinus.

Passer domesticus.
Calcarius ornatus.
Rhynchophanes mccownii.
Junco caniceps.
Pipilo fuscus mesoleucus.
Ampelis cedrorum.
Cinclus mexicanus.
Catherpes mexicanus conspersus.
Troglodytes hiemalis.
Certhia familiaris montana.
Sitta carolinensis.
Sitta calolinensis aculeata.
Sitta canadensis.
Sitta pygmæa.
Parus inornatus griseus.
Parus atricapillus septentrionalis.
Parus gambeli.
Psaltriparus plumbeus.
Myadestes townsendii.

2. Winter visitants; species that have been taken commonly in the State during the winter, but are not included in the foregoing list.

Urinator imber.
Merganser serrator.
Aythya americana.
Aythya vallisneria.
Aythya affinis.
Charitonetta albeola.
Chen hyperborea.
Archibuteo lagopus sancti-johannis.
Otocoris alpestris leucolæma.
Coccothraustes vespertinus montanus.
Acanthis linaria.
Plectrophenax nivalis.
Leucosticte tephrocotis.
Leucosticte tephrocotis littoralis.
Calcarius lapponicus.
Zonotrichia leucophrys intermedia.
Spizella monticola ochracea.
Junco aikeni.
Junco hyemalis connectens.
Junco mearnsi.
Junco annectens.
Pipilo maculatus arcticus.
Ampelis garrulus.
Lanius borealis.

3. Species that breed in the State and regularly winter further south, but a few occur irregularly in southern Colorado in winter and in mild winters may occur throughout the State.

Podilymbus podiceps.
Larus delawarensis.
Anas carolinensis.
Branta canadensis.
Grus mexicana.
Gallinago delicata.
Falco columbarius.
Agelaius phœniceus.
Sturnella magna neglecta.
Scolecophagus cyanocephalus.
Zonotrichia leucophrys.
Melospiza fasciata montana.
Cistothorus palustris paludicola.
Merula migratoria.
Merula migratoria propinqua.
Sialia mexicana bairdi.
Sialia arctica.

4. Species that have been taken in Colorado in winter, either as rare or accidental visitors.

Stercorarius parasiticus.
Rissa tridactyla.
Larus argentatus smithsonianus.
Larus atricilla.
Xema sabinii.
Aythya marila nearctica.
Harelda hyemalis.
Oidemia americana.
Oidemia deglandi.
Oidemia perspicillata.
Branta canadensis hutchinsii.
Accipiter atricapillus striatulus.
Buteo borealis harlani.
Nyctea nyctea.
Colaptes auratus.
Scolecophagus carolinus.
Loxia leucoptera.
Leucosticte atrata.
Zonotrichia coronata.
Junco hyemalis.
Melospiza fasciata.
Cardinalis cardinalis.

5. Summer residents; species that have been known to breed in the state.

A. Species that breed on the plains and in the mountains or mountain parks.

Colymbus nigricollis californicus.
Larus delawarensis.
Hydrochelidon nigra surinamensis.
Anas boschas.
Anas strepera.
Anas americana.
Anas carolinensis.
Anas discors.
Anas cyanoptera.
Spatula clypeata.
Aix sponsa.
Erismatura jamaicensis.
Botaurus lentiginosus.
Ardea herodias.
Grus mexicana.
Porzana carolina.
Fulica americana.
Recurvirostra americana.
Himantopus mexicanus.
Totanus solitarius.
Symphemia semipalmata inornata.
Actitis macularia.
Ægialitis vocifera.
Ægialitis montana.
Centrocercus urophasianus.
Meleagris gallopavo mexicana.
Zenaidura macroura.
Cathartes aura.
Circus hudsonius.
Accipiter velox.
Accipiter cooperi.
Buteo borealis calurus.
Buteo swainsoni.
Archibuteo ferrugineus.
Falco mexicanus.
Falco peregrinus anatum.
Falco columbarius.
Falco richardsonii.
Falco sparverius.
Asio wilsonianus.
Asio accipitrinus.
Bubo virginianus subarcticus.
Speotyto cunicularia hypogæa.
Coccyzus americanus occidentalis.
Ceryle alcyon.
Dryobates villosus hyloscopus.
Dryobates pubescens h orus.
Ceophlœus pileatus.

Melanerpes erythrocephalus.
Colaptes cafer.
Phalænoptilus nuttalli.
Chordeiles virginianus henryi.
Tyrannus tyrannus.
Tyrannus verticalis.
Tyrannus vociferans.
Myiarchus cinerascens.
Sayornis saya.
Empidonax difficilis.
Empidonax traillii.
Otocoris alpestris arenicola.
Pica pica hudsonica.
Corvus cryptoleucus.
Corvus americanus.
Molothrus ater.
Xanthocephalus xanthocephalus.
Agelaius phœniceus.
Sturnella magna neglecta.
Icterus bullocki.
Scolecophagus cyanocephalus.
Carpodacus mexicanus frontalis.
Spinus tristis.
Spinus psaltria.
Spinus psaltria arizonæ.
Chondestes grammacus strigatus.
Poocætes gramineus confinis.
Spizella socialis arizonæ.
Spizella pallida.
Spizella breweri.
Melospiza fasciata montana.
Pipilo maculatus megalonyx.
Oreospiza chlorura.
Pipilo fuscus mesoleucus.
Zamelodia melanocephala.
Passerina amœna.
Progne subis.
Petrochelidon lunifrons.
Chelidon erythrogastra.
Clivicola riparia.
Stelgidopteryx serripennis.
Ampelis cedrorum.
Lanius ludovicianus excubitorides.
Vireo gilvus.
Dendroica æstiva.
Icteria virens longicauda.
Setophaga ruticilla.
Oroscoptes montanus.
Galeoscoptes carolinensis.
Troglodytes ædon aztecus.
Cistothorus palustris paludicola.
Merula migratoria propinqua.
Sialia arctica.

B. Species that breed on the plains, but only to the foothills of the mountains.

Podilymbus podiceps.
Sterna forsteri.
Pelecanus erythrorhynchos.
Dafila acuta.
Nycticorax nycticorax nævius.
Rallus virginianus.
Steganopus tricolor.
Bartramia longicauda.
Numenius longirostris.
Colinus virginianus.
Pediocætes phasianellus campestris.
Callipepla californica.
Meleagris gallopavo.
Buteo borealis kriderii.
Strix pratincola.
Megascops asio.
Conurus carolinensis. (formerly)
Icterus galbula.
Quiscalus quiscula æneus.
Passer domesticus.
Calcarius ornatus.
Rhynchophanes mccownii.
Spizella socialis.

Ammodramus savannarum perpallidus.
Spiza americana.
Calamospiza melanocorys.
Vireo olivaceus.
Dendroica striata.
Geothlypis trichas occidentalis.
Mimus polyglottos.
Harporhynchus rufus.
Sitta carolinensis.
Merula migratoria.
Sialia sialis.

C. Species that breed in the mountains or mountain parks and not on the plains.

Merganser americanus.
Lophodytes cucullatus.
Clangula islandica.
Histrionicus histrionicus.
Branta canadensis.
Gallinago delicata.
Dendragapus obscurus.
Bonasa umbellus umbelloides.
Lagopus leucurus.
Accipiter atricapillus.
Pandion haliætus carolinensis.
Nyctala acadica.
Megascops flammeola.
Glaucidium gnoma.
Picoides americanus dorsalis.
Aëronautes melanoleucus.
Contopus borealis.
Empidonax wrightii.
Cyanocitta stelleri macrolopha.
Perisoreus canadensis capitalis.
Nucifraga columbiana.
Cyanocephalus cyanocephalus.
Pinicola enucleator.
Carpodacus cassini.
Loxia curvirostra stricklandi.
Leucosticte australis.
Zonotrichia leucophrys.
Junco caniceps.
Melospiza lincolnii.
Passerella iliaca schistacea.
Piranga ludoviciana.
Helminthophila virginiæ.
Helminthophila celata.
Helminthophila celata lutescens.
Dendroica auduboni.
Dendroica townsendi.
Geothlypis macgillivrayi.
Sylvania pusilla.
Anthus pensilvanicus.
Cinclus mexicanus.
Troglodytes hiemalis.
Certhia familiaris montana.
Sitta canadensis.
Sitta pygmæa.
Parus gambeli.
Regulus satrapa.
Regulus calendula.
Myadestes townsendii.
Turdus fuscescens salicicola.
Turdus ustulatus swainsonii.
Turdus aonalaschkæ auduboni.
Sialia mexicana bairdi.

D. Species that breed principally in the mountains, and but sparingly on the plains.

Aquila chrysaetos.
Haliæetus leucocephalus.
Megascops asio maxwelliæ.
Megascops asio aikeni.
Sphyrapicus varius nuchalis.
Sphyrapicus thyroideus.
Melanerpes torquatus.
Selasphorus platycercus.

Contopus richardsonii.
Aphelocoma woodhousei.
Corvus corax sinuatus.
Spinus pinus.
Ammodramus sandwichensis alaudinus.
Tachycineta bicolor.
Tachycineta thalassina.
Vireo solitarius plumbeus.
Salpinctes obsoletus.
Catherpes mexicanus conspersus.
Sitta carolinensis aculeata.
Parus atricapillus septentrionalis.

E. Species that breed regularly only in southern Colorado.

Callipepla gambeli.
Columba fasciata.
Syrnium occidentale.
Geococcyx californianus.
Dryobates scalaris bairdi.
Cypseloides niger borealis.
Trochilus alexandri.
Selasphorus rufus.
Amphispiza bilineata.
Amphispiza belli nevadensis.
Pipilo aberti.
Guiraca cærulea eurhyncha.
Compsothlypis americana.
Dendroica æstiva sonorana.
Dendroica graciæ.
Dendroica nigrescens.
Thryothorus bewickii leucogaster.
Parus inornatus griseus.
Psaltriparus plumbeus.
Polioptila cærulea.

6. Species taken in the State during the summer, but not known to breed.

Ajaja ajaja.
Plegadis guarauna.
Ardea candidissima.
Philohela minor.
Callipepla squamata.
Melopelia leucoptera.
Coccyzus erythrophthalmus.
Melanerpes carolinus.
Phalænoptilus nuttalli nitidus.
Dolichonyx oryzivorus.
Icterus spurius.
Junco phæonotus dorsalis.
Passerina cyanea.
Mniotilta varia.
Seiurus aurocapillus.

7. Migrants; species that have been taken in the State during the spring or fall, but are not known to breed or winter in Colorado.

Æchmophorus occidentalis.
Colymbus holbœllii.
Colymbus auritus.
Larus occidentalis.
Larus californicus.
Larus franklinii.
Larus philadelphia.
Sterna paradisæa.
Phalacrocorax dilophus.
Anas obscura.

Aythya collaris.
Clangula clangula americana.
Chen hyperborea nivalis.
Anser albifrons gambeli.
Olor columbianus.
Olor buccinator.
Guara rubra.
Grus americana.
Grus canadensis.
Gallinula galeata.
Phalaropus lobatus.
Macrorhampus scolopaceus.
Micropalama himantopus.
Tringa maculata.
Tringa fuscicollis.
Tringa bairdii.
Tringa minutilla.
Tringa alpina pacifica.
Ereunetes pusillus.
Ereunetes occidentalis.
Calidris arenaria.
Limosa fedoa.
Totanus melanoleucus.
Totanus flavipes.
Numenius hudsonicus.
Squatarola squatarola.
Charadrius dominicus.
Ægialitis semipalmata.
Arenaria interpres.
Myiarchus lawrencei olivascens.
Sayornis phœbe.
Empidonax minimus.
Carpodacus purpureus.
Ammodramus bairdii.
Zonotrichia querula.
Zonotrichia albicollis.
Piranga rubra cooperi.
Helminthophila peregrina.
Dendroica cærulescens.
Dendroica coronata.
Dendroica maculosa.
Dendroica rara.
Seiurus noveboracensis notabilis.
Sylvania pusilla pileolata.
Harporhynchus bendirei.
Turdus aonalaschkæ.
Turdus aonalaschkæ pallasii.
Saxicola œnanthe.

8. Stragglers or doubtful species, including those of which but one instance is known.

Æchmophorus occidentalis.
Colymbus holbœllii.
Colymbus auritus.
Rissa tridactyla.
Larus occidentalis.
Larus californicus.
Larus atricilla.
Anas obscura.
Chen hyperborea nivalis.
Branta bernicla.
Ajaja ajaja.
Guara alba.
Guara rubra.
Tantalus loculator.
Ardetta exilis.
Ardea rufescens.
Nycticorax violaceus.
Gallinula galeata.
Callipepla squamata.
Melopelia leucoptera.
Elanoides forficatus.
Ictinia mississippiensis.
Accipiter atricapillus striatulus.
Buteo lineatus elegans.
Coccyzus erythrophthalmus.
Sphyrapicus varius.
Milvulus forficatus.
Myiarchus lawrencei olivascens.

Sayornis phœbe.
Icterus spurius.
Scolecophagus carolinus.
Carpodacus purpureus.
Zonotrichia querula.
Zonotrichia coronata.
Zonotrichia albicollis.
Melospiza fasciata.
Cardinalis cardinalis.
Piranga rubra cooperi.
Vireo solitarius cassinii.
Dendroica cærulescens.
Dendroica rara.
Seiurus aurocapillus.
Icteria virens.
Sylvania pusilla pileolata.
Harporhynchus bendirei.
Turdus aonalaschkæ pallasii.
Saxicola œnanthe.

9. Regular visitants from the east or southeast.

Colaptes auratus.
Tyrannus tyrannus.*
Quiscalus quiscula æneus.*
Spizella socialis.*
Spiza americana.*
Helminthophila celata.*
Compsothlypis americana.*
Dendroica coronata.
Galeoscoptes carolinensis.*
Harporhynchus rufus.*
Sitta carolinensis.*
Polioptila cærulea.*
Merula migratoria.*
Sialia sialis.*

*Breeding.

10. Rare or irregular visitants from the east or southeast.

Xema sabinii.
Anas obscura.
Branta bernicla.
Ajaja ajaja.
Philohela minor.
Elanoides forficatus.
Ictinia mississippiensis.
Coccyzus erythrophthalmus.
Sphyrapicus varius.
Melanerpes carolinus.
Phalænoptilus nuttalli nitidus.
Milvulus forficatus.
Sayornis phœbe.
Dolichonyx oryzivorus.
Icterus spurius.
Icterus galbula.
Scolecophagus carolinus.
Carpodacus purpureus.
Zonotrichia querula.
Zonotrichia albicollis.
Melospiza fasciata.
Cardinalis cardinalis.
Passerina cyanea.
Vireo olivaceus.
Mniotilta varia.
Helminthophila peregrina.
Dendroica cærulescens.
Dendroica maculosa.
Dendroica rara.
Dendroica striata.
Seiurus aurocapillus.
Icteria virens.
Saxicola œnanthe.

11. Regular visitants from the west or southwest.

Anas cyanoptra.
Grus canadensis.
Columba fasciata.
Glaucidium gnoma.
Geococcyx californianus.
Dryobates scalaris bairdi.

Cypseloides niger borealis.
Trochilus alexandri.
Selasphorus rufus.
Myiarchus cinerascens.
Amphispiza bilineata.
Amphispiza belli nevadensis.
Pipilo fuscus mesoleucus.
Guiraca cærulea eurhyncha.
Dendroica graciæ.
Dendroica nigrescens.
Dendroica townsendi.
Catherpes mexicanus conspersus.
Parus inornatus griseus.
Psaltriparus plumbeus.

NOTE. All of these species have been found breeding in Colorado except *Grus canadensis*.

12. Rare or irregular visitants from the west or southwest.

Plegadis guarauna.
Callipepla squamata.
Callipepla gambeli.*
Melopelia leucoptera.
Accipiter atricapillus striatulus.
Zonotrichia coronata.
Myiarchus lawrencei olivascens.
Junco phæonotus dorsalis.
Pipilo aberti.*
Piranga rubra cooperi.
Vireo solitarius cassinii.
Turdus aonalaschkæ.

*Breeding.

SUMMARY.

Total species in Colorado	360
1. Residents	87
2. Regular winter visitants from the north	24
3. Regular breeders that sometimes occur in winter	17
4. Rare or accidental winter visitants	22
5. Summer residents	228
A. Breeding on plains and in mountains	101
B. Breeding on plains, but not in mountains	34
C. Breeding in mountains, but not on plains	53
D. Breeding principally in mountains, sparingly on plains	20
E. Breeding regularly only in southern Colorado	20
6. Summer visitants, not known to breed	15
7. Migrants	58
8. Stragglers	48
9. Regular visitants from east and southeast	14
10. Rare visitants from east and southeast	33
11. Regular visitants from west and southwest	20
12. Rare visitants from west and southwest	12

DATES OF MIGRATION.

The notes on migration given in the following table are designed to show the different time at which the same species of birds arrive at different places and altitudes in Colorado as compared with the time of their arrival in the same latitude farther east and at a lower altitude. St. Louis, Mo., is thirty miles farther north than Fort Lyon, Colo., and one hundred and twenty miles south of Loveland, Colo. Hence, according to latitude, the birds should arrive in St. Louis about the same time as at Fort Lyon. But it is found that in fact they reach St. Louis on the average about twelve days before they appear at Fort Lyon. The dates of arrival seem to indicate an average difference of six days between Fort Lyon and Loveland. The distance between these two places is one hundred and fifty miles, or an average movement for the birds of twenty-five miles per day. This agrees quite closely with the average of twenty-eight miles per day that was found to be the usual speed of migration in the Mississippi valley.

The birds arrive at Idaho Springs about twenty-five days later than at Loveland, the result of the nearly three thousand feet more of altitude at the former place.

The records that follow for St. Louis, Mo., were taken by Mr. O. Widmann during the spring of 1884, and published on pages 33-37 of "Bird Migration in Mississippi Valley." The records for Fort Lyon were made by Capt. P. M. Thorne, U. S. A., and those at Loveland by Mr. Wm. G. Smith. These records were made for the Division of Ornithology and Mammalogy of the Department of Agriculture at Washington, and the present writer is indebted to the chief of the division, Dr. C. Hart Merriam, for copies of these records. The notes from Idaho Springs are those taken by Mr. T. M. Trippe, and published by Dr. Coues in "Birds of the Northwest."

It is understood, of course, that when dates are given for western varieties that do not occur at St. Louis, it is meant that the western variety was noted in Colorado and its eastern representative at St. Louis. Thus, *merula migratoria propinqua* was seen at Fort Lyon, while *merula migratoria* was the bird seen at St. Louis.

All the dates given are those on which the first individuals of the species were seen.

DATES OF ARRIVAL.

	St. Louis, Mo., 1884.	Ft. Lyon, Colo., 1883–1886.	Loveland, Colo., 1887–1890.	Idaho Springs, Colo., 1873.
Dafila acuta	Jan. 30	Mch. 14–Apr. 1	Jan. 27–Feb. 10	
Aythya americana		Feb. 22–Mch. 1	Feb. 2–Mch. 6	
Anas carolinensis	Feb. 18	Feb. 20–Mch. 3	Feb. 21	
Anas strepera		Mch. 1	Mch. 1–12	
Sialia arctica		Mch. 16–17	Mch. 6–16	Mch. 10
Aythya vallisneria		Apr. 7	Feb. 10–Mch. 12	
Larus delawarensis		Mch. 23	Mch. 9–20	
Spatula clypeata			Mch. 10–20	
Aythya affinis		Mch. 27–Apr. 10	Mch. 8–19	
Anas americana			Mch. 10–13	
Merula migratoria propinqua	Jan. 30	Mch. 14–18	Feb. 25–Mch. 15	Mch. 15
Ægialitis vocifera	Mch. 11	Mch. 9–12	Mch. 10–16	
Charitonetta albeola		Mch. 27–Apr. 1	Mch. 20	
Chen hyperborea	Feb. 25	Apr. 7	Mch. 21	
Falco sparverius	Feb. 26	Apr. 4–20	Mch. 21–29	
Anas cyanoptera		Mch. 7	Mch. 25–Apr. 13	
Anas discors		Mch. 1	Mch. 25–Apr. 13	
Fulica americana		Mch. 31	Mch. 10–25	
Totanus melanoleucus		Mch. 28–Apr. 10	Mch. 26–Apr. 6	
Falco peregrinus anatum			Mch. 29	
Tringa bairdii			Mch. 29–Apr. 9	
Sialia mexicana bairdi			Apr. 1	
Sayornis saya		Mch. 1–Apr. 15	Mch. 31–Apr. 15	
Oroscoptes montanus			Apr. 4–15	May 10
Pipilo maculatus megalonyx	Feb. 20	Apr. 16	Apr. 4–19	May 15
Zonotrichia leucophrys	Feb. 20		Apr. 4	
Erismatura jamaicensis	Feb. 26	Mch. 27–Apr. 10	Mch. 27–Apr. 5	
Ægialitis montana		Mch. 26	Mch. 27–Apr. 18	
Speotyto cunicularia hypogæa			Mch. 28–Apr. 7	
Grus americana	Mch. 17		Apr. 8–16	
Pandion haliaëtus carolinensis			Apr. 8	
Rallus virginianus			Apr. 9	
Lanius ludovicianus excubitorides	Jan. 30		Apr. 9–14	
Zenaidura macroura	Mch. 22	Mch. 22–Apr. 17	Apr. 11–14	
Xanthocephalus xanthocephalus		Apr. 23	Apr. 11–12	
Recurvirostra americana		Mch. 28	Apr. 9–23	
Numenius longirostris			Apr. 10–15	
Anthus pensilvanicus			Apr. 14–15	May 10
Totanus flavipes		Mch. 30	Apr. 15	
Podilymbus podiceps			Apr. 15–28	
Poocætes gramineus confinis	Mch. 22	Apr. 13	Apr. 17	May 10
Cathartes aura	Feb. 26		Apr. 10–22	
Scolecophagus cyanocephalus		Apr. 22	Apr. 18–25	
Dendroica auduboni		Apr. 29–May 12	Apr. 19–24	May 15
Tringa minutilla		Apr. 28–May 7	Apr. 19–23	
Totanus solitarius	May 5		Apr. 20	
Ammodramus savannarum perpallidus	Apr. 30		Apr. 21	
Actitis macularia	Mch. 17	May 12–17	Apr. 21	May 10
Ammodramus sandwichensis alaudinus	Mch. 22		Apr. 21	
Ardea herodias		Apr. 10	Apr. 11–21	
Pelecanus erythrorhynchus			Apr. 23	
Chelidon erythrogaster		Apr. 17	Apr. 23	
Progne subis	Mch. 24		Apr. 21–24	
Petrochelidon lunifrons	Apr. 15	May 6–8	Apr. 24	

DATES OF ARRIVAL—Continued.

	St. Louis. Mo., 1884.	Ft. Lyon, Colo., 1883–1886.	Loveland, Colo., 1887–1890.	Idaho Springs, Colo., 1873.
Nycticorax nycticorax nævius			Apr. 25	
Ægialitis meloda circumcincta			Apr. 25–May 5	
Dendroica coronata	Apr. 13	Apr. 17	Apr. 24–25	Apr. 25
Turdus aonalaschkæ auduboni		May 6–9	Apr. 25–May 7	May 25
Myadestes townsendii		Apr. 22–23	Apr. 25	Resident
Spizella pallida		Apr. 25	Apr. 25	
Tachycineta thalassina			Apr. 26	
Stelgidopteryx serripennis	Apr. 15		Apr. 28	
Limosa fedoa			Apr. 20–May 1	
Tringa alpina pacifica			Apr. 29–May 9	
Macrorhampus scolopaceus		May 2	Apr. 29	
Melospiza fasciata montana	Feb. 23		Apr. 29	
Steganopus tricolor			Apr. 27–May 1	
Salpinctes obsoletus		Apr. 20	Apr. 29–May 8	May 20
Cistothorus palustris paludicola			Apr. 30	
Colymbus nigricollis californicus			Apr. 26–30	
Spizella socialis arizonæ	Mch. 22		Apr. 30	
Phalaropus lobatus			May 1–9	
Helminthophaga celata	May 10	May 9	May 2–5	
Melospiza lincolnii	Apr. 29	Apr. 30	May 5	May 10
Symphemia semipalmata inornata		May 2	Apr. 27–May 5	
Clivicola riparia	Apr. 29		May 5	
Tachycineta bicolor	Mch. 24		May 5	
Sterna forsteri			May 5	
Oreospiza chlorura		Apr. 30–May 8	May 6	May 10
Larus franklinii			May 6	
Ereuntes pusillus		Apr. 25	May 6	
Dendroica æstiva	Apr. 19	Apr. 17–May 8	May 7–19	
Passerina amœna		May 8–15	May 7–19	
Chondestes grammacus strigatus	Apr. 25	Apr. 27	May 7	
Tyrannus verticalis		May 5–6	May 8–12	
Contopus richardsonii		May 22	May 8	May 25
Tyrannus tyrannus	Apr. 18	May 6–10	May 7–9	
Turdus ustulatus swainsonii	Apr. 26	May 6	May 9–10	
Setophaga ruticilla	Apr. 17	May 14	May 9	May 20
Dendroica nigrescens			May 9	
Icterus bullocki		May 4–12	May 9–19	
Geothlypis trichas occidentalis	Apr. 18	May 13	May 9	
Ereuntes occidentalis			May 9	
Calamospiza melanocorys		May 10–15	May 9–12	
Troglodytes aëdon aztecus	Apr. 19	Apr. 21–May 10	May 10	May 15
Piranga ludoviciana			May 10–17	June 20
Harporhynchus rufus	Mch. 22	May 4–10	May 10	
Geothlypis macgillivrayi		May 2–3	May 10–19	May 25
Vireo solitarius plumbeus	Apr. 29		May 11	May 25
Galeoscoptes carolinensis	Apr. 25	May 8–14	May 11–12	May 20
Contopus borealis		May 11	May 11	
Vireo gilvus	Apr. 19		May 12	
Vireo olivaceus	Apr. 26	May 29	May 12	
Dendroica striata	Apr. 29	May 8	May 12	
Empidonax minimus	Apr. 29		May 12	
Mimus polyglottos	Apr. 14	Apr. 17–May 2	May 13	
Sylvania pusilla	May 6	May 5	May 11–13	May 20
Aëronautes melanoleucus			May 13	
Botaurus lentiginosus		Apr. 26	May 13	
Zamelodia melanocephala		May 19–20	May 13	May 20
Helminthophaga peregrina	Apr. 29		May 17	
Micropalama himantopus		May 2–22	May 20	

BIBLIOGRAPHY OF COLORADO ORNITHOLOGY.

The following list of publications, concerning the birds of Colorado, is believed to be practically complete with the following exceptions: No record has been made of the reviews or notices that have appeared of these publications. Some twenty-three articles have been omitted as being but incidental references and having no valuable bearing on the subject matter in hand.

One important particular should be noted in regard to the following pages. While referring to the book or article by its title as a whole, the explanatory notes have reference to only that part of the work that deals with Colorado birds as such explicitly. All implied references have been neglected. Even such a broad and comprehensive statement as "found in the entire Rocky Mountain region" has not been deemed sufficient to warrant considering it a Colorado reference. No reference whatever is made to all that part of the publications that deals with other matters.

The names of the authors are arranged alphabetically and the articles under each author in chronological order.

AIKEN, C. E. and HOLDEN, C. H. JR. Notes on the Birds of Wyoming and Colorado Territories. By C. H. Holden, Jr. with additional memoranda by C. E. Aiken. *Proc. Bost. Soc. Nat. Hist. XV.* 1872, *pp. 193–210.*

The paper is edited by T. M. Brewer who states that Mr. Holden's notes are based on birds and eggs found "in the northern part of Colorado and southern part of Wyoming Territories." As no record is given of the precise localities where each species was obtained, Mr. Holden's notes cannot be quoted with any certainty as referring to Colorado.

The records of Mr. Aiken were taken near Fountain, El Paso County, between November 1, 1871 and May 1872, and formed an important contribution to the knowledge of Colorado birds. The paper treats of 142 species, fully annotated, of which 59 are for the first time accredited to Colorado.

AIKEN, C. E. A Glimpse at Colorado and its Birds. *Am. Nat. VII.* 1873, *p. 13.*

Field notes on 21 species of birds seen in October in El Paso County.

AIKEN, C. E. A New Species of Sparrow. *Am. Nat. VII.* 1873, *p. 236.*

Description of *Centronyx ochrocephalus* since ascertained to be a synonym of *A. bairdii.* Taken in El Paso County, Colorado.

AIKEN, C. E. The Nidification of the Blue Crow and of the Gray-headed Snowbird. *Am. Sportsman, V.* 1875, *p. 370.*

Contains the first published description of the nest and eggs of the Blue Crow (*Cyanocephalus cyanocephalus*) also the first description of the nest and eggs of the Gray-headed Snowbird (*Junco caniceps*).

AIKEN, C. E. Notes on the Ornithology [of Colorado] observed by Mr. C. E. Aiken, Assistant. *Ann. Rep't Chief of Engineers,* 1875, *part II. Appendix LL, p. 1070.*

A short sketch of the birds observed by him in a trip from Pueblo to Pagosa Springs and return by way of the San Luis Valley. These notes, in a much fuller form, are included in H. W. Henshaw's report on the Birds of the Geographical Explorations and Surveys west of the one hundredth meridian.

ALLEN, J. A. Notes of an Ornithological Reconnoissance of portions of Kansas, Colorado, Wyoming and Utah. *Bull. Mus. Comp. Zool. III.* 1872, *pp. 113-183.*

A notable paper for the student of the historical side of Colorado Ornithology, as it contains the first real "local list" ever published of Colorado birds. All that had been written previous to this time on the birds of Colorado treats of less than twenty-five species, while this paper mentions more than three times that number. It is not meant that no ornithologists previous to this time had visited Colorado, but that their observations had not at this time been published. Mr. Allen's paper contains in addition to notes on birds from other states, a list of birds observed in Colorado, July-August, 1871 (81 species); in South Park, Colorado, July, 1871 (54 species); on Mount Lincoln, Colorado, July, 1871 (36 species). Of these 84 species are for the first time accredited to Colorado.

ALLEN, J. A. and BREWSTER, WM. List of Birds Observed in the Vicinity of Colorado Springs, Colorado, during March, April and May, 1882. *B. N. O. C. VIII.* 1883, *pp. 151 and 189.*

Notes on the arrival, abundance and breeding of 134 species. Also technical notes by Mr. Brewster on the specific characters of 14 species. The first and only records for Colorado of Bendire's Thrasher and the Florida Gallinule are given here. Mr. Brewster here gives the original description of *Helminthophila celata lutescens*, but without including Colorado in its geographical range, where however it has been taken by subsequent observers.

ALLEN, J. A. On the Avi-Fauna of Pinal County, with Remarks on some Birds of Pima and Gila Counties, Arizona. By W. E. D. Scott, with annotations by J. A. Allen. *Auk, V.* 1888, *p. 160.*

States that *Troglodytes aëdon aztecus* is the form found in Colorado.

ALLEN, J. A. The North American Species of the Genus *Colaptes* considered with Special Reference to the Relationships of *C. auratus* and *C. cafer*. *Bull. Am. Mus. Nat. Hist. IV. No. 1,* 1892, *article II. p. 21.*

Considers that true *auratus*, true *cafer* and also the mixed forms are found in Colorado.

AMERICAN ORNITHOLOGISTS' UNION. The Code of Nomenclature and Check List of North American Birds, adopted by the American Ornithologists' Union, being the Report

of the Committee of the Union on Classification and Nomenclature. New York: American Ornithologists' Union, 1886.

Contains specific Colorado references to 35 species.

AMERICAN ORNITHOLOGISTS' UNION. Check List of North American Birds, prepared by a Committee of the American Ornithologists' Union. Second and Revised Edition. New York: American Ornithologists' Union, 1895.

Contains specific Colorado references to 53 species.

ANTHONY, A. W. Winter Plumage of *Leucosticte australis*. *Auk, IV.* 1887, *p. 257.*

Description of the plumage of male, female and young, based on specimens taken at Gold Hill, Colorado.

ANTHONY, A. W. The Scaled Partridge (*Callipepla squamata*) in Colorado. *Auk, XII.* 1895, *p. 388.*

A freshly killed bird seen in a taxidermist shop during the winter of 1892-3; said to have been killed on the Platte River near Denver.

BAIRD, S. F., CASSIN, J. and LAWRENCE, G. N. Reports of Explorations and Surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean. Made under the direction of the Secretary of War in 1853-6, according to Acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854. Vol. IX. Birds: by Spencer F. Baird, Assistant Secretary Smithsonian Institution, with the co-operation of John Cassin and George N. Lawrence.

Capt. Gunnison's party and that of Lieut. Warren brought back skins and records of about twenty species of birds that have nothing but an historical value in this connection. They are included in the above volume with the records of the other surveying parties.

BAIRD, S. F. Pacific Railroad Reports as above, Vol. X. Route near the 38th and 39th parallels explored by Captain J. W. Gunnison, and near the 41st parallel, explored by Lieutenant E. G. Beckwith. Zoological Report No. 2. Report of Birds Collected on the Survey. By S. F. Baird.

Contains much the same notes from Gunnison's party that had already been printed in Vol. IX. Unimportant records of 15 species.

BAIRD, S. F. Geological Survey of California. J. D. Whitney, State Geologist. Ornithology, Vol. 1. Land Birds. Edited by S. F. Baird from the manuscript and notes of J. G. Cooper. Published by authority of the legislature, 1870, pp. XI., 591.

The only reference to Colorado ornithology is the appearance here under the name of *Leucosticte campestris* of a specimen of *Leucosticte tephrocotis* sent from Denver to the Smithsonian, January, 1862, by Dr. C. Wernigk. This is the first record for this species from Colorado.

BAIRD, S. F., BREWER, T. M. and RIDGWAY, R. A History of North American Birds. Land Birds, Vol. I.–[III.]. Boston, Little, Brown and Company, 1874. 3 vols.

Contains specific Colorado references on 54 species, nothing of which is new material.

BATCHELDER, C. F. Description of the First Plumage of Clarke's Crow. *Auk, Vol. I.* 1884, *p. 16.*

Specimens obtained in Chaffee County, Colorado.

BATCHELDER, C. F. An Undescribed Subspecies of *Dryobates pubescens. Auk, VI.* 1889, *p. 253.*

Describes *D. p. oreœcus* (=*homorus*) with type from Loveland, Colorado.

BATTY, J. H. The U. S. Geological Survey. *Forest and Stream, I. August 28,* 1873, *p. 35.*

Brief notes of a trip from Denver to Buffalo Peaks. Mentions seven species of common birds and in addition says: "I have also taken the nest, eggs and young of the *Regulus calendula* (ruby-crowned wren), which have never been taken before."

BATTY, J. H. The White-tailed Ptarmigan—*Lagopus leucurus. Forest and Stream, I. January 29,* 1874, *p. 390.*

Seen in winter in the foothills of South Park, Colorado.

BECKHAM, C. W. The Black-headed Grosbeak (*Zamelodia melanocephala*). *O. and O. VIII.* 1883, *p. 63.*

Notes on the nest and eggs. A male seen incubating near Pueblo, Colorado.

BECKHAM, C. W. Notes on Some of the Birds of Pueblo, Colorado. *Auk, II.* 1885, *p. 139.*

Brief records of the movements of 91 species of birds. Contains the first record for Colorado of *Thryothorus bewickii leucogaster* and, with one exception, the only record to date.

BECKHAM, C. W. Additional Notes on the Birds of Pueblo County, Colorado. *Auk, IV.* 1887, *p. 120.*

Addition of 22 species to the 91 previously noted and further notes on 28 species in the original list. First records for Colorado of *Zonotrichia querula* and *Z. albicollis.* There has been a second specimen of the latter taken; the former remains the only record for the state.

BENDIRE, C. E. Notes on the Habits, Nests and Eggs of the Genus *Sphyrapicus* Baird. *Auk, V.* 1888, *p. 226.*

Contains extended notes by Mr. Dennis Gale on the habits of *S. v. nuchalis* in Colorado.

BENDIRE, C. E. Notes on the Habits, Nests and Eggs of the Genus *Glaucidium* Boie. *Auk, V.* 1888, *p. 366.*

States that the form found in Colorado is *G. gnoma.*

BENDIRE, C. E. A Peculiar Nest of *Cinclus mexicanus. Auk, VI.* 1889, *p. 75.*

Describes one taken by Mr. Dennis Gale at Gold Hill.

BENDIRE, C. E. *Picicorous columbianus* (Wils.), Clarke's Nutcracker. Its Nest and Eggs, etc. *Auk, VI.* 1889, *p. 226.*

Notes made by Mr. Dennis Gale at Gold Hill, Colorado, together with a reprint of Bendire's description of the first nest and eggs ever taken, specimens procured in Oregon, (*Bendire, O. & O. 1882. pp. 105-107 and 113-114*); and a reprint of Goss' description of the nest he found at Fort Garland, Colorado, (*Goss, B. N. O. C., VIII. 1883, p. 44*). Mr. Gale's specimens are the third known to science.

BENDIRE, C. E. Description of the Nest and Eggs of *Megascops asio maxwelliæ*, the Rocky Mountain Screech Owl. *Auk, VI.* 1889, *p. 298.*

The first nest known was taken by Mr. A. W. Anthony near Denver; also several nests taken by Mr. Dennis Gale near Gold Hill.

BENDIRE, C. E. *Megascops asio maxwelliæ.* *Auk, VII.* 1890, *p. 91.*

Results of the examination of three ejected pellets sent by Mr. Dennis Gale from Gold Hill.

BENDIRE, C. E. A Second Nest and Eggs of *Picicorvus columbianus* taken in Colorado. *Auk, VII.* 1890, *p. 92.*

Taken by Mr. Dennis Gale at Gold Hill.

BENDIRE, C. E. Smithsonian Institution. United States National Museum. Special Bulletin No. 1. Life Histories of North American Birds, with special reference to their Breeding Habits and Eggs, with twelve lithographic plates. By Charles Bendire, Captain U. S. Army (retired), Honorary Curator of the Department of Oölogy, etc. pp. VIII. 446. Washington: Government Printing Office, 1892.

Descriptions of the nests and eggs of many species of Quail, Grouse, Doves, Hawks and Owls, of which 26 are specifically mentioned as occurring in Colorado. Contains many interesting and valuable notes by Mr. Dennis Gale, of Gold Hill, Colorado, on the breeding habits of birds in the Rocky Mountains.

BENDIRE, C. E. Smithsonian Institution. United States National Museum. Special Bulletin [No. 3.] Life Histories of North American Birds from the Parrots to the Grackles, with special reference to their Breeding Habits and Eggs. By Charles Bendire, Captain and Brevet Major U. S. A. (retired). Honorary Curator of the Department of Oölogy, U. S. National Museum, Member of the American Ornithologists' Union. With seven lithographic plates. Washington: Government Printing Office, 1895. pp. I-IX. 1-518.

This is Part II. of the work quoted above as Special Bulletin No. 1. It has the same general plan and style and the notes come from the same sources.

BRACKETT, A. E. Jack Snipe in Colorado. *Forest and Stream IX.* 1877, *p. 397.*

BRENINGER, G. F. Lincoln's Sparrow and its Nesting. *O. & O. XII.* 1887, *p. 191.*
Nest with young taken July 5 at 12,000 feet.

BRENINGER, G. F. Nesting of the Western Yellow Warbler. *O. & O. XIII.* 1888, *p. 64.*
Short note on its breeding habits.

BRENINGER, G. F. Nesting of the Green-tailed Towhee. *O. & O. XIII.* 1888, *p. 90.*
Eggs taken late in June at 7,000 feet.

BREWER, T. M. Exhibition of a Pair of *Plectrophanes maccowni* from "California," *i. e.*, Colorado. *Proc. Bos. Soc. Nat. Hist. XV.* 1873, *p. 311.*

BREWER, T. M. Note on the Nesting and Eggs of *Logopus leucurus. Proc. Bost. Soc. Nat. Hist. XVI.* 1874, *p. 348.*
Taken by Mr. T. M. Trippe at Idaho Springs, Colorado, June 28, 1873, a thousand feet above timber-line.

BREWER, T. M. [Letter on the Nest and Eggs of *Dendrœca auduboni.*] *Ibis, 4th Series* 1877, *p. 394.*
Fully described specimens from Summit County, Colorado.

BREWER, T. M. Notes on *Junco caniceps* and the Closely Allied Forms. *B. N. O. C. III.* 1878, *p. 72.*
Nest and eggs taken by J. H. Batty. Egg also taken July 12, 1876, in South Park.

BREWER, T. M. The Rocky Mountain Golden-eye (*Bucephala islandica*). *B. N. O. C. IV.* 1879, *p. 148.*
First eggs in the United States probably taken by Edwin Carter in 1876

BREWER, T. M. The Rocky Mountain Whiskey Jack (*Perisoreus canadensis capitalis*). *B. N. O. C. IV.* 1879, *p. 239.*
Nest taken by Mr. Carter, April 2, 1879, at Breckenridge.

BREWSTER, WM. On a Collection of Birds lately made by Mr. F. Stephens in Arizona. *B. N. O. C. VIII.* 1883, *p. 21.*
Refers to the occurrence of the Chapparel Cock in Colorado.

BREWSTER, WM. and ALLEN, J. A. See Allen, J. A. and Brewster, Wm. *B. N. O. C. VIII.* 1883, *pp. 151 and 189.*

BREWSTER, WM. Bendire's Thrasher (*Harporhynchus bendirei*) in Colorado. *B. N. O. C. VIII.* 1883, *p. 57.*
First and only capture in Colorado.

Brewster, Wm. Recent Occurrence of the Flammulated Owl in Colorado. *B. N. O. C. VIII.* 1883, *p. 123.*

Note from Mr. C. E. Aiken recording a young bird in nestling plumage taken near Manitou, and one taken at Mosca Pass, at the same place where Dr. Walbridge shot one four years previous.

Brewster, Wm. The Red Crossbill (*Loxia curvirostra stricklandi*) in Kansas. By L. L. Dyche. *Auk, III.* 1886, *p. 260.*

With a supplementary note by Mr. Brewster in which he states that Colorado specimens are much nearer *stricklandi* than *americana.*

Brewster, Wm. Three New Forms of North American Birds. *Auk, IV.* 1887, *p. 145.*

Describes a new subspecies *Symphemia semipalmata inornata* with types from Larimer County, Colorado.

Brewster, Wm. On Three Apparently New Subspecies of Mexican Birds. *Auk, V.* 1888, *p. 139.*

The Colorado *Dendroica æstiva* is considered as a fair intermediate between *sonorana* and *morcomi.*

Brewster, Wm. Descriptions of Seven Supposed New North American Birds. *Auk, VIII.* 1891, *p. 139.*

Includes *Megascops asio aikeni* with type from El Paso County, Colorado.

Burns, Frank L. The American Crow, (*Corvus americanus*) with Special Reference to its Nest and Eggs. Bull. No. 5 The Wilson Ornithological Chapter of the Agassiz Association, pp. 1-41. Oberlin, Ohio, March 15, 1895. H. Kenaston's print, Oberlin, Ohio.

Contains notes from Colorado by Mr. F. M. Dille.

Byers, W. N. Birds and Electric Light. *Forest and Stream, XVIII.* 1882, *366*

Destruction of large numbers of birds by flying against the framework of the electric light towers in Denver, Colorado.

Cantwell, Geo. C. Doings of a Tenderfoot. *O. & O. XV.* 1890, *p. 104.*

Short notes on several species of common birds seen near Pike's Peak.

Coale, H. K. Ornithological Notes of a Flying Trip through Kansas, New Mexico, Arizona and Texas. *Auk, XI.* 1894, *p. 216.*

A few notes on five species of the winter birds of Fort Logan, near Denver, Colorado.

Cockerell, T. D. A. The Second Report of the Colorado Biological Association. *Custer County Courant* [local newspaper], *December*, 1888.

Note from Chas. F. Morrison giving record of the capture of *Ajaja ajaja* at Silverton, Colorado.

COCKERELL, T. D. A. The Sixth Report of the Colorado Biological Association. *Custer County Courant*, *January* 16, 1889.

Note from H W. Nash of the recent capture of the Pygmy Owl near Pueblo.

COCKERELL, T. D. A. The Ninth Report of the Colorado Biological Association. "Our Spring Migrants," T. D. A. C[ockerell]. *Custer County Courant*, *February*, 1889.

Dates of arrival for 1888 of 11 species.

COCKERELL, T. D. A. The Thirteenth Report of the Colorado Biological Association. *Custer County Courant*, *March*, 1889.

Robins first seen near Short Creek, March 19, 1889.

[Oversheets of all these reports were issued, unpaged and mostly undated].

COOKE, W. W. Ten New Birds for Colorado. *Auk*, *XI.* 1894, *p. 182.*

Records of some 15 species, of which *Oidemia deglandi*, *Ardetta exilis*, *Calidris arenaria* and *Coccyzus erythrophthalmus*, proved to be new birds for the State.

COOKE, W. W. The Summer Range of Colorado Birds. *Auk*, *XII.* 1895, *p. 151.*

Gives recapitulation of the altitudes at which the birds breed in the State, but mentions only a few species by name.

COUES, E. Range of the *Geococcyx californianus*. *Am. Naturalist*, *VII.* 1873, *p. 751.*

Quotes a letter from Dr. A. Woodhull on the occurrence of this species on the Arkansas River near Fort Lyon, Colorado.

COUES, E. Department of the Interior. United States Geological Survey of the Territories. F. V. Hayden. U. S. Geologist in Charge. Miscellaneous Publications No. 3. Birds of the Northwest. A Hand-book of The Ornithology of the Region drained by the Missouri River and its Tributaries. By Elliott Coues, Captain and Assistant Surgeon U. S. Army. Washington: Government Printing Office, 1874. pp. XII. 791.

A large part of Colorado falling within the scope of this volume, there is here collected nearly all that had been written on Colorado birds up to this time. One hundred and forty-five species are attributed specifically to Colorado, in addition to many whose habitat includes Colorado by implication. But the most important part of the work with reference to Colorado, is the very full and valuable notes of Mr. T. M. Trippe on the birds in the vicinity of Idaho Springs. They form to-day the best record there is of the vertical movements of the birds in spring and fall migration.

COUES, E. On the Breeding Habits, Nest and Eggs of the White-tailed Ptarmigan (*L. leucurus*). *Bull. U. S. Geological Surv. Terr. 2d series*, *No. 5*, *January* 8, 1876, *pp. 263–266.*

Most of the material on which these notes are based came from Colorado.

COUES, E. The Destruction of Birds by Telegraph Wire. *Am. Naturalist, X.* 1876, *p. 734.*

A detailed account from observations in Colorado.

COUES, E. Range of the Lanier Falcon. *B. N. O. C. II.* 1877, *p. 26.*

Very numerous in open portions of Colorado.

COUES, E. Western Range of *Conurus carolinensis. B. N. O. C. II.* 1877, *p. 50.*

Letter from Mr. E. L. Berthoud of its occurrence from 1860 to 1862 at Golden, Denver, on the Little Thompson, and on the Arkansas River near old Fort Lyon.

COUES, E. Note on the Cinnamon Teal. *B. N. O. C. II.* 1877, *p. 51.*

This and several other species very abundant, breeding at a small lake in North Park, Colorado.

COUES, E. *Melopelia leucoptera* in Colorado. *B. N. O. C. II.* 1877, *p. 83.*

Note from Mr. E. L. Berthoud of seeing a dozen or more, July, 1869, at the head of Cub Creek, Jefferson County, Colorado.

COUES, E. Nest and Eggs of *Selasphorus platycercus. B. N. O. C. III.* 1878, *p. 95.*

Record of five nests found by Mr. E. A. Barber, July 26, 1875, in extreme southwestern Colorado.

COUES, E. Department of the Interior, United States Geological Survey of the Territories. F. V. Hayden, U. S. Geologist in charge. Miscellaneous Publications No. 11. Birds of the Colorado Valley. A Repository of Scientific and Popular Information Concerning North American Ornithology. By Elliott Coues. Part First. *Passeres* to *Laniidæ.* Bibliographical Appendix. Seventy Illustrations. pp. XVI. 807. Washington: Government Printing Office, 1878.

Contains a good deal of material on Colorado birds, but it is all quoted from Henshaw's Report on the Surveys West of the Hundredth Meridian. q. v.

COUES, E. Nest and Eggs of *Catherpes mexicanus conspersus. B. N. O. C. V.* 1880, *p. 181.*

Nest with five eggs taken by Mr. H. D. Minot at Manitou, June 8, 1880.

COUES, E. Nest and Eggs of *Myiadestes townsendii. B. N. O. C. VIII.* 1883, *p. 239.*

Description of nest and eggs found by Mr. Wm. G. Smith in Jefferson County, Colorado.

COUES, E. Nest and Eggs of *Parus montanus. B. N. O. C. VIII.* 1883, *p. 239.*

Description of both taken by Mr. Wm. G. Smith.

COUES, E. Key to North American Birds, Etc. Fourth Edition, 1890.

Gives specific Colorado references for 35 species.

DAVIE, OLIVER. Nests and Eggs of North American Birds. By Oliver Davie. The Fourth Edition. Introduction by J. Parker Norris. Illustrations by Theodore Jasper, A. M., M. D., and W. Otto Emerson. pp. XII. 451. Columbus, Hann & Adair, 1889.

Contains specific references to 77 species of birds as breeding in Colorado.

DEANE, RUTHVEN. Capture of a Third Specimen of the Flammulated Owl (*Scops flammeola*) in the United States and First Discovery of its Nest. *B. N. O. C. IV.* 1879, *p. 188.*

Taken by Mr. C. E. Aiken at Poncha Pass, Fremont County, June 15, 1875; also the nest with one egg. This is the first record of its breeding in Colorado.

DEANE, RUTHVEN. The Old Squaw (*Clangula hyemalis*) in Colorado. *Auk, XII.* 1895, *p. 292.*

A male and female, shot by Mr. John B. Sibley near Denver, November 13, 1892. This is the first record for Colorado.

DILLE, F. M. Nesting of *Archibuteo ferrugineus. Young Oölogist*, 1885, *pp. 44, 45.*

Nesting April 13, 1885, in Weld County.

DILLE, F. M. A Week's Trip after Hawk's Eggs in Colorado. *O. & O. XII.* 1887, *p. 97.*

Eggs or young of *B. b. kriderii*, *B. b. calurus*, *B. swainsoni*, *A. ferrugineus*, and *F. mexicanus*, taken May 20-25, 1886, in Weld County.

DILLE, F. M. Nesting of the Black-billed Magpie. *O. & O. XIII.* 1888, *p. 23.*

Eggs on the plains usually about the first of May; in the mountains by May 25.

DILLE, F. M. Home Life of the Mountain Bluebird. *Nidologist, II.* 1894-5, *p. 36.*

Notes on the nesting of the Rocky Mountain Bluebird and the House Finch.

DILLE, F. M. Colorado Birds. The Black-billed Magpie. *The Sunny South Oölogist, I. No. 1.*

DILLE, F. M. Egg Collecting in Colorado. *The Sunny South Oölogist, I. No. 2.*

DILLE, F. M. Colorado Birds. Lark Bunting and Mountain Plover. *The Sunny South Oölogist, I. No. 3.*

DREW, F. M. Field Notes on the Birds of San Juan County, Colorado. *B. N. O. C. VI.* 1881, *pp. 85 and 138.*

Notes of the occurrence, migration and breeding of 104 species that range to or above 10,000 feet. Contains the first Colorado records of *Histrionicus histrionicus, Ceophlœus pileatus, Cypseloides niger, Loxia leucoptera* and *Dendroica graciæ.*

DREW, F. M. Song of the White-bellied Swallow (*Iridoprocne bicolor*). *B. N. O. C. VI.* 1881, *p. 115.*

"A peculiar chirrupy warble, bearing resemblance to a sparrow's song in some respects and strikingly like a robin's in some of the half-whistles."

DREW, F. M. The Golden-crested Wren Breeding in the Colorado Valley. *B. N. O. C. VI.* 1881, *p. 244.*

A young bird just from the nest, taken in San Juan County, Colorado, on July 25, 1881, at 11,000 feet.

DREW, F. M. *Lopibes hyperboreus* at 9,500 feet. *B. N. O. C. VI.* 1881, *p. 249.*

Six killed by flying against the telegraph wires.

DREW, F. M. Notes on the Plumage of *Nephœcetes niger borealis.* *B. N. O. C. VII.* 1882, *p. 182.*

Believes that four years are necessary to acquire full plumage.

DREW, F. M. Notes on *Lagopus leucurus.* *Auk, 1,* 1884, *p. 392.*

On the moulting of the toe-nails of specimens taken in southern Colorado.

DREW, F. M. On the Vertical Range of Birds in Colorado. *Auk, II.* 1885, *p. 11.*

One of the most notable articles ever written on Colorado birds. It gives: 1. The highest altitude at which each species is known to range in the spring. 2. The same for the summer. 3. The same for the autumn. 4. The upper and lower limits of altitude, between which the species ranges during the winter. 5. The upper and lower limits of the breeding range.

The list is preceded by a short sketch of the topography of the state and a brief summary of its meteorological conditions.

The article is intended to present a complete list of the birds of Colorado known to that time. It contains 277 species classified as follows:

1. Residents, 51. 2. Summer residents, known to breed, 156. 3. Total breeders, 207. 4. Migrants, 21. 5. Winter visitants, 22. 6. Summer visitants, not known to breed, 5. 7. Known to occur within the state, but not classified, 22. TOTAL, 277.

The article contains the first records for Colorado of *Colymbus holbœllii, Colinus virginianus, Callipepla californica* and *Cardinalis cardinalis.*

DWIGHT, JONATHAN, JR. The Horned Larks of North America, *Auk, VII.* 1890, *p. 138.*

Breeding birds of Colorado said to be *arenicola.*

FISHER, A. K. U. S. Department of Agriculture. Division of Ornithology and Mammalogy. Bulletin No. 3. The Hawks and Owls of the United States in their Relation to Agriculture. Prepared under the direction of Dr. C. Hart

Merriam, Ornithologist, by A. K. Fisher, M. D., Assistant Ornithologist. Published by authority of the Secretary of Agriculture. pp. 210. Washington: Government Printing Office, 1893.

Specific Colorado references to 12 species.

GOSS, B. F. Notes on the Breeding Habits of Maximilian's Jay (*Gymnocitta cyanocephala*) and Clarke's Crow (*Picicorvus columbianus*). *B. N. O. C. VIII.* 1883, *p. 43.*

Description of nests and eggs found near Fort Garland, Colorado.

GOSS, N. S. Notes on the Breeding Habits of the American Eared Grebe (*Dytes nigricollis californicus*). *Auk*, *I.* 1884, *p. 19.*

Observations on the notes of Mr. Henshaw concerning the nesting of this species in the San Luis Valley.

GOSS, N. S. Additions to the Catalogue of Kansas Birds. *Auk*, *III.* 1886, *p. 114.*

Records the Chapparel Cock in southeastern Colorado and southwestern Kansas.

GOSS, N. S. Additions to the Catalogue of the Birds of Kansas with Notes in Regard to their Habits. *Auk*, *VI.* 1889, *p. 123.*

Describes nest of Clarke's Nutcracker taken at Fort Garland, Colorado.

HASBROUCK, E. M. The Carolina Paroquet (*Conurus carolinensis*) *Auk*, *VIII.* 1891, *p. 378.*

Refers to its former occurrence in Colorado.

HASBROUCK, E. M. The Geographical Distribution of the Genus *Megascops* in North America. *Auk*, *X.* 1893, *p. 250.*

The distribution of *M. a. maxwelliæ* and of *M. a. aikeni* in Colorado is given with the authorities and references; also full records to date of all the captures of *M. flammeola* in Colorado.

HENSHAW, H. W. Engineering Department, U. S. Army. Geographical and Geological Explorations and Surveys west of the one hundredth meridian. First Lieutenant Geo. M. Wheeler, Corps of Engineers, in Charge. Report upon Ornithological Specimens collected in the years 1871, 1872 and 1873. Washington: Government Printing Office, 1874, pp. 148.

In addition to various other articles on the birds of New Mexico, Arizona and Utah, it contains an article by Mr. Henshaw on 82 species found at Denver, May, 1873, and another on 104 species at Fort Garland, Colorado.

HENSHAW, H. W. Eared Grebe (*Podiceps auritus* var. *Californicus* Coues.) *Am. Nat. VIII.* 1874, *p. 243.*

An account of its breeding in San Luis Park.

HENSHAW, H. W. Engineering Department, U. S. Army. Report upon Geographical and Geological Explorations and Surveys west of the one hundredth meridian, in charge of First Lieut. Geo. M. Wheeler, Corps of Engineers, U. S. Army, under the direction of Brig. Gen. A. A. Humphreys, Chief of Engineers, U. S. Army. Published by Authority of Hon. Wm. W. Belknap, Secretary of War, in accordance with Acts of Congress of June 23, 1874, and February 15, 1875. In six volumes, accompanied by one topographical and one geological atlas. Washington: Government Printing Office, 1875. Vol. V. Zoology, Chapter III. Report upon the Ornithological Collections made in portions of Nevada, Utah, California, Colorado, New Mexico and Arizona, during the years 1871, 1872, 1873 and 1874, by H. W. Henshaw. pp. 133-507, plates XV.

Observations on the distribution and breeding of birds as noted by the various parties. So far as Colorado is concerned, it is a reprint of the paper noted above by Mr. Henshaw and all that had been previously written by Mr. C. E. Aiken on Colorado birds, with the addition of much new matter. It gives specific Colorado records for 170 species, of which 14 are here for the first time attributed to the State. The whole makes one of the most valuable contributions to Colorado ornithology.

HENSHAW, H. W. The Shore Larks of the United States and Adjacent Territory. *Auk*, *I.* 1884, *p. 257.*

States that *leucolæma* occurs in Colorado only as a winter visitant and that all breeding birds are *arenicola.*

HENSHAW, H. W. List of Birds Observed in Summer and Fall on the Upper Pecos River, New Mexico. *Auk*, *II.* 1885, *p. 333*, and concluded in *Auk*, *III.* 1886, *p. 79.*

Contains Colorado notes on Baird's Sparrow, Red Crossbill and Pigmy Owl.

HERSEY, J. CLARENCE. The Little White Egret (*Ardea candidissima*) in Colorado. *Am. Naturalist*, *X.* 1876, *p. 430.*

A specimen taken at Boulder, May 4, 1876.

HOLDEN, C. H., JR. and AIKEN, C. E. See Aiken, C. E. and Holden, C. H., Jr.

INGERSOLL, EARNEST. Our Present Knowledge of the Nidification of the American Kinglets. *B. N. O. C. I.* 1876, *p.* 77.

Records a nest with five young and one egg, found by Mr. J. H. Batty, near Buffalo Mountain, June 21, 1873, being the first ever known to science.

INGERSOLL, EARNEST. The Flammulated Owl (*Scops flammeola*) in Colorado. *B. N. O. C. V.* 1880 *p. 121.*

Records a second specimen for Colorado, shot by Dr. Walbridge at Mosca Pass, the third week in August, 1879.

"J" [CAPT. P. M. THORNE]. Range of *Carpodacus frontalis. Forest and Stream, XXI.* 1883, *No. 26, p. 493.*

A pair killed at Fort Lyon, Colorado, June 3, 1883, the female containing eggs nearly ready to lay.

JEFFRIES, J. AMORY. Notes on an Hermaphrodite Bird. *B. N. O. C. VIII.* 1883, *p. 17.*

A Green-tailed Finch from Colorado Springs, Colorado.

KELLOGG, V. L. Summer Birds of Estes Park, Colorado. *Trans. Kans. Acad. Science, XII.* 1889-90, *p. 86.*

Annotated list of 89 species, among them being *Colinus virginianus, Columba fasciata, Pinicola enucleator* and *Sitta carolinensis* [typical].

LAMB, W. F. Nest and Eggs of Townsend's Flycatcher. *B. N. O. C. II.* 1877, *p. 77.*

First nest ever known to science found by him in Summit County, Colorado, in July, 1876, at an elevation of 10,000 feet.

LOWE, W. P. Some Spring Arrivals at Pueblo County, Colorado. *O. & O. XVII.* 1892, *p. 101.*

Dates of arrival of about 70 species, including *Polioptila cærulea.*

LOWE, W. P. A List of the Birds of the Wet Mountains, Huerfano County, Colorado. *Auk, XI.* 1894, *p. 266.*

Annotated list of 76 species, giving their vertical distribution.

LOWE, W. P. The Scarlet Ibis (*Guara rubra*) in Colorado. *Auk, XI.* 1894, *p. 324.*

A fine specimen shot in the Wet Mountains in May, 1876. This is the fourth record of its capture in the United States.

LOWE, W. P. An Addition to the Birds of Colorado. *Auk, XII.* 1895, *p. 298.*

Capture of *Callipepla squamata*, June 10, 1895, in the eastern foothills of the Wet Mountains, Pueblo County, Colorado, at an altitude of 6,000 feet.

LOWE, W. P. The arrival of the English Sparrow at Pueblo. *Nidiologist, II.* 1894-5, *p. 99.*

First seen there February 20, 1895, and quite common a week later.

LOWE, W. P. Notes from the Field. *Nidiologist, II,* 1894-5, *p. 169.*

Heights of nesting sites of several hawks and owls.

MAYNARD, CHAS. J. Eggs of North American Birds. By Chas. J. Maynard. Illustrated with ten Hand-colored Plates. pp. IV. 159. Boston: DeWolfe, Fiske & Co., 1890.

Specific Colorado breeding references for 22 species.

MCGREGOR, R. C. *Junco ridgwayi* in Colorado. *Auk, X.* 1893, *p. 205.*

One taken near Boulder.

McGregor, R. C. Two Runts. *The Nidiologist, II. May, 1895, p. 119.*

A set of eggs of Swainson's Hawk, taken in Weld County, Colo., June 1, 1887, contained one "runt" egg.

McGregor, R. C. Birds of Estes Park. *Nidiologist, IV. 1896-7, p. 38.*

Short notes on the occurrence of 76 species.

Merrill, J. C. Oölogical Notes from Montana. *B. N. O. C. VI.* 1881, *p. 204.*

Refers to the fact that the first four nests of the Ruby-crowned Kinglet known to science came from Colorado.

Miller, Olive Thorne. A Bird Lover in the West. Boston and New York: Houghton, Mifflin & Company. The Riverside Press, Cambridge, 1894. pp. I-VII. 1-278.

Notes on the habits and nesting of several species of birds found in the vicinity of Colorado Springs.

Minot, H. D. Notes on Colorado Birds. *B. N. O. C. V.* 1880, *p. 223.*

Annotated notes on 44 species taken at Boulder, 5,000 feet altitude; Nederland, 8,000 feet, and Seven Lakes, near Manitou, 11,000 feet altitude. The first and only record for *Saxicola œnanthe*, taken at Boulder, May 14, 1880.

Morrison, C. F. Field Notes on some Birds of Colorado. *O. & O. XI.* 1886, *pp. 153 and 164*, continued in *O. & O. XII.* 1887, *p. 27 and 35, 58 and 106.*

Notes on 31 species taken at Fort Lewis, Colorado. The "Pinnated Grouse" referred to is of course the "Sharp-tailed Grouse."

Morrison, C. F. A List of Some Birds of La Plata County, Colorado, with Annotations. *O. & O. XIII.* 1888, *p. 70, 107, 115 and 139.*

Quite full notes on 116 species, with the first record for Colorado of *Meleagris gallopavo mexicana.*

Morrison, C. F. A List of the Birds of Colorado. *O. & O. XIII.* 1888, *p. 145, 165 and 181*, continued in *O. & O. XIV.* 1889, *p. 6, 65 and 145*, concluded in *O. & O. XV.* 1890, *p. 36.*

The most extensive list of Colorado birds published up to this time. Begins with No. 1 of the A. O. U. Check List and closes with No. 570 a, enumerating 233 species. The list was never completed, owing to the destruction by fire of much of the material. In addition to records of Colorado birds already in print, the author had the use of a large amount of unpublished notes sent him by local collectors. The list, if completed at that time, would have shown 326 species; but as the records of some fourteen species recorded here have since been ascertained to be incorrect, it would reduce the real number to 312, or 35 more than Mr. Drew's list published three years previous. In this list appear for the first time *Ajaja ajaja*, *Tringa fuscicollis*, *Callipepla gambeli*, *Nyctea nyctea*, and *Junco phæonotus dorsalis.*

NASH, H. W. Notes on Some Birds Breeding in Colorado. *Forest and Stream, Feb. 5*, 1880.

Short observations on the nests and eggs of 28 species breeding near Pueblo.

NASH, H. W. Colorado Bird Arrivals. *Forest and Stream, XX. April 19*, 1883, *p. 225*.

Dates of arrival of the Eastern Bluebird and the Western Meadow Lark.

NORRIS, J. P. A series of Eggs of Sitta pygmæa. *O. & O. XIII.* 1888, *p. 173*.

One set was taken in Estes Park, Colorado, May 29, 1886.

OSBURN, WM. Nesting of the Grebes. *O. & O. XV.* 1890, *p. 68*.

Notes on the breeding of *Podilymbus podiceps* near Loveland, Colorado.

OSBURN, WM. Birds of Rare occurrence in Northern Colorado. *Science, XXII.* 1893, *p. 212*.

Notes on nine species seldom found there, among which *Zonotrichia coronata* is the first and only record for Colorado.

PEABODY, P. B. Glossy Ibis at Heron Lake. *Nidiologist, II.* 1895, *p. 116*.

Refers to a mounted specimen in his possession taken near Colorado Springs, Colorado.

PEARCE, GORDON D. Water Ousel or American Dipper. *The Sunny South Oölogist, I. No. 1.*

POLK, BURR H. A Mallard's Strange Nesting Place. *Forest and Stream, XVIII.* 1882, *p. 427*.

On the open prairie in eastern Colorado.

RIDGWAY, ROBERT. On Some New Forms of North American Birds. *Am. Nat. VII.* 1873, *pp. 603 and 615*.

Describes *Catherpes mexicanus conspersus* taken in Colorado by Aiken and Allen and *Junco hyemalis aikeni* taken by Aiken near Fountain, El Paso County, in the winter of 1871–2.

RIDGWAY, R. The Birds of Colorado. *Bull. Essex Inst. V.* 1873, *p. 174*.

The first list of Colorado birds ever published; 243 species, of which 156 are noted as breeding. The center of abundance of each species during the breeding season is also given. The list is preceded by several tables. Eastern species found in Colorado, 30. Others found at more western points, not yet detected in Colorado, 15. [Eleven of these have since been taken in Colorado, and one more only three miles north of the State in Wyoming.] Species of the southern border of the United States found in Colorado, 10. Western species found in Colorado not occurring in corresponding latitudes in the Great Basin, 5. The list is followed by critical notes on several species.

RIDGWAY, ROBERT. Description of a New Bird (*Leucosticte atrata*) from Colorado. *Am. Sportsman, IV.* 1874, *p. 241*.

Four specimens taken by C. E. Aiken at Canon City, in April, 1874.

RIDGWAY, ROBERT. Mrs. Maxwell's Colorado Museum; Catalogue of the Birds. *Field and Forest II.* 1887, *pp. 195-198 and 208-214.*

A list of the 234 species in the collection, several of which are the first and some the first and only records for Colorado.

RIDGWAY, ROBERT. Mrs. Maxwell's Colorado Museum; Additional Notes. *Field and Forest III.* 1887, *p. 11.*

Notes on two species *Junco caniceps* and *Junco annectens.*

RIDGWAY, ROBERT. *Scops flammeola* in Colorado. *B. N. O. C. V.* 1880, *p. 185.*

Calls attention to the fact that his record of the specimen in Mrs. Maxwell's collection is the real first record of the species for Colorado.

RIDGWAY, ROBERT. A Review of the American Crossbills (*Loxia*) of the *L. curvirostra* Type. *Proc. Biolog. Soc. of Washington, II.* 1883, *p. 84.*

Describes a new subspecies, *L. c. bendirei*, as the form occurring in Colorado and adjacent territory. [The A. O. U. have since refused to admit the validity of this subspecies.]

RIDGWAY, ROBERT. On the Possible Specific Identity of *Buteo cooperi* Cass. with *B. harlani* (Aud.). *Auk, I.* 1884, *p. 253.*

A specimen taken by Mr. C. E. Aiken at Colorado Springs.

RIDGWAY, ROBERT. On *Buteo harlani* (Aud.) and *B. Cooperi* Cass. *Auk, II.* 1885, *p. 165.*

Shows that Aiken's Colorado specimen should be considered *harlani* instead of *cooperi.*

RIDGWAY, ROBERT. A Manual of North American Birds. By Robert Ridgway. Illustrated by 464 Outline Drawings of the Generic Characters. *pp. XI. 631. Plates CXXIV.* Philadelphia: J. B. Lippincott Company, 1887.

Gives specific Colorado references to 34 species, one of which, *Coccyzus americanus occidentalis* is here described for the first time and attributed to Colorado, and *Guiraca cærulea eurhyncha* is for the first time stated to be the form found in Colorado.

"R. V. R. S." Winter Snipe in Colorado. *Forest and Stream XXVI.* 1886, *No. 1, p. 5.*

Wilson's Snipe reported as occurring about warm spring holes in the coldest winter weather.

SAY, THOMAS. Account of an Expedition from Pittsburg to the Rocky Mountains, performed in the years 1819 and '20 by order of the Hon. J. C. Calhoun, Secretary of War; under the command of Major Stephen H. Long. From the notes of Major Long, Mr. T. Say, and other gentlemen of the party. Compiled by Edwin James, botanist and

geologist for the expedition. In two vols. With an atlas. Vol. I. [II.]. Philadelphia: H. C. Carey and I. Lea, Chestnut St. 1823.

All Colorado matter is contained in the second volume, where eight species new to science are described and the type localities given; also short notes on three species previously described.

SCOTT, W. E. D. Notes on Birds observed at Twin Lakes, Lake County, Colorado. *B. N. O. C. IV.* 1879, *p. 90.*

Annotated list of 60 species, giving dates of nesting and notes on occurrence.

SMITH, H. G. JR. The Shore Lark (*Eremophila cornuta*). *O. & O. IX.* 1884, *p. 95.*

Notes on its habits and breeding at Denver.

SMITH, H. G. JR. Notes from Denver, Colorado. *O. & O. IX.* 1884, *p. 120.*

Notes on the Bohemian Waxwing, House Finch and Say's Flycatcher.

SMITH, H. G. JR. Cassin's Purple Finch (*Carpodacus cassini*). *O. & O. X.* 1885, *p. 90.*

Several seen at Denver, February 26 to March 25, 1885.

SMITH, H. G. JR. Some Additions to the Avi-fauna of Colorado. *Auk, III.* 1886, *p. 284.*

Ten species not given in Mr. Drew's list of Colorado birds. Of these the Rusty Grackle, Cormorant and Herring Gull are the first and only records for Colorado.

SMITH, H. G. JR. Food of the Great Northern Shrike. *O. & O. XIII.* 1888, *p. 163.*

Occurs as a winter resident at Denver, capturing Shorelarks and Longspurs; also feeding on grasshoppers and other insects.

SMITH, H. G. Another *Megascops flammeolus* for Colorado. *Auk, X.* 1893, *p. 364.*

One taken in Jefferson County.

SMITH, H. G. City Birds of Denver, Colorado. *Science XXII.* 1893, *p. 244.*

Short notes on 32 species.

SMITH, H. G. Some Birds New to Colorado. With notes on others of little known distribution in the State. *The Nidologist III.* 1896, *pp. 48, 65, 76.*

An important contribution to our knowledge of several species. Notes on 35 species, mostly water birds, of which *Æchmophorus occidentalis, Larus atricilla, Sterna paradisæa, Oidemia perspicillata, Gaura alba, Arenaria interpres, Strix pratincola, Dendroica cærulescens* and *Turdus aonalaschkæ* are the first records for Colorado.

SMITH, W. G. [Winter Birds in Larimer County, Colorado.] By W. G. S[mith]. *Random Notes, III.* 1886, *p. 13.*

SMITH, W. G. [Nest of Rock Wren.] *Random Notes, III.* 1886, *p. 17.*

SMITH, W. G. [Nest and Eggs of *Myiadestes townsendii.*] *Random Notes, III.* 1886, *p. 25.*

SMITH, W. G. [Notes from Colorado.] *Random Notes, III.* 1886, *pp. 66 and 67.*

SMITH, W. G. Nesting of Audubon's Warbler. *O. & O. XVIII.* 1888, *p. 114.*

SMITH, W. G. Nesting of the Ruddy Duck. *O. & O. XIII.* 1888, *p. 132.*

SMITH, W. G. Nesting of the Water Ousel. *O. & O. XIII.* 1888, *p. 149.*

SMITH, W. G. Nesting of the Pied-billed Grebe. *O. & O. XIV.* 1889, *p. 138.*

SMITH, W. G. Breeding Habits of the Mountain Plover. *O. & O. XIII.* 1888, *p. 187.*

SMITH, W. G. Nesting of the Cinnamon Teal. *O. & O. XIV.* 1889, *p. 77.*

SMITH, W. G. Sabine's Gull. *O. & O. XIV.* 1889 *p. 176.*

One killed at Loveland, October 12, 1889.

SMITH, W. G. Nesting of the Eared Grebe. *O. & O. XV.* 1890, *p. 140.*

SMITH, W. G. Nesting of the Flammulated Screech Owl. *O. & O. XVI.* 1891, *p. 27.*

Eggs at 10,000 feet on June 2, 1890, and another nest June 4. On June 20, a nest at 8,000 feet. [It is probable that all these were found in Estes Park.]

STONE, D. D. Water Ousel and Canada Jay. *O. & O. VII.* 1882, *p. 181.*

A Water Ousel seen at 11,000 feet in October near an open place in the ice on a small lake during a snow storm. Canada Jay so tame as to alight on his arm and take bread from his hand.

STONE, D. D. Notes from Colorado. *O. & O. VII. 1882, p. 191.*

Notes on 16 species taken at about 11,000 feet, Pine Grosbeak in July. Description of nest and eggs of "Oregon (?) Snowbird" and "Mountain Mocking Bird."

[In *O. & O. VIII.* 1883, *p. 13*, Mr. R. Ridgway has a note saying that Mr. Stone's "Mountain Mocking Bird" is *Myiadestes townsendii*, the "Oregon Snow Bird" is *Junco caniceps*, the "Stellar's Jay" is the Long-crested and the "Canada Jay" is the White-headed Jay, *Perisoreus capitalis.*]

STONE, D. D. Ruby-Crowned Kinglet. *O. & O. VIII.* 1883, *p. 83.*

Description of nests and eggs taken near Hancock, Colorado.

STONE, D. D. Colorado Notes. Extracts from may Note-book. *O. & O. IX.* 1884, *Part 1, p. 9. Part 2, p. 20.*

Notes on the nests and eggs of 18 species of birds nesting above 11,000 feet.

STONE, D. D. [*Myiadestes townsendii* and *Sialia sialis.*] *Random Notes, III.* 1886, *p. 42.*

THORNE, P. M. The Eastern Bluebird at Fort Lyon, Colorado. *Auk, III.* 1886, *p. 489.*

A pair nested there in 1886.

THORNE, P. M. Additions to Drew's List of Colorado Birds. *Auk, IV.* 1887, *p. 264.*

Notes on 20 species taken in the vicinity of Fort Lyon. [Of these *Contopus pertinax*, *Melospiza georgiana*, *Vireo belli*, *Anthus spragueii*, *Thryothorus ludovicianus*, *Thryothorus bewickii* and *Turdus fuscescens* are now known to be errors of identification.]

THORNE, P. M. Abnormal Plumage of *Xanthocephalus xanthocephalus. Auk, V.* 1888, *p. 112.*

Taken in Las Animas County, Colorado.

THORNE, T. W. [P. M.] The Olivaceous Flycatcher and Phœbe in Colorado. *Auk, VI.* 1889, *p. 276.*

Both taken at Fort Lyon; the first and only records for the state.

[WOOD, C. S.] *Scops flammeola. Colorado Springs Gazette, Sept. 3*, 1879.

Exhibition by C. E. Aiken of the fourth specimen from the United States.

WOODBURY, A. H. Ring-billed Gull in Colorado. O. *& O. XII.* 1887, *p. 116.*

One taken at Monte Vista.

THE HISTORY OF COLORADO ORNITHOLOGY.

In an old State like Massachusetts or New York whose birds have been studied and written about for nearly two centuries, it would be almost a hopeless task to collect and digest the enormous mass of material. In Colorado the case is far different. Less than fifty years have elapsed since the first systematic study of Colorado birds was made and but little was done previous to 1870. Yet in twenty-five years many records have been lost and the Colorado list shows already nearly a dozen species known to have been taken in the State, but the data of whose capture, when, where and by whom, cannot now be found.

This shows that it is high time a permanent record should be made of the principal facts in Colorado Ornithology while these facts are obtainable.

1807. **Pike.** The first reference to any birds residing in Colorado is found in Lieut. Pike's account of his trip through the State. He mentions the raven, magpie, turkey and pheasant. From what is now known it seems probable that he refers to *corvus corax sinuatus*, *pica pica hudsonica*, *meleagris gallopavo* and *dendragapus obscurus*, but as this is guess work in the case of two of these species, all of them are repeated under the name of the next one who reported them.

1823. **Say.** The expedition of Maj. Long was accompanied by the first trained ornithologist, who entered the bounds of the present State of Colorado. Thos. Say has left us records of the capture during that trip of *dendragapus obscurus*, *columba fasciata*, *tyrannus verticalis*, *pica pica hudsonica*, *carpodacus mexicanus frontalis*, *spinus psaltria*, *passerina amœna*, *petrochelidon lunifrons*, *mimus polyglottos*, *salpinctes obsoletus* and *merula migratoria*.

1858. **Baird.** The government parties of the Pacific Railroad surveys traveled but little in Colorado. The following is a list of all the government expeditions that entered Colorado previous to 1860:

1806–7. Lieut. Pike. Up the Arkansas River to Canon City, across into South Park; then by a round-about way into the San Luis Valley and to New Mexico.

1820. Maj. Long. Up the South Platte to Denver; across the "Divide" to Colorado Springs and south into New Mexico.

1844 and 1845. Capt. Fremont. Across the State via Grand River, Pueblo, Denver and Fort Morgan.

1851. Capt. Pope. Came from New Mexico north and east to La Junta and east to Kansas.

1853. Capt. Gunnison. Crossed the plains to the Arkansas River, up that stream and its branches to Trinidad, Colorado, across southern Colorado to Fort Massachusetts, over the Continental divide to the Gunnison River, down this stream and the Grand River to Utah.

1855. Lieut. Warren. Just touched Colorado at Julesburg.

1856. Lieut. Bryan. Up the South Platte to Fort Morgan and north into Wyoming.

1859. Col. Loring and Capt. Macomb. Across the southwest corner of Colorado in passing from Utah to New Mexico.

The specimens collected by these various expeditions, together with the field notes of the naturalists were worked up by Prof. Baird and his assistants, and incorporated in the ninth volume of the Pacific Railroad Reports. There occur here the first specific Colorado references to *anas discors*, *aythya americana*, *grus mexicana*, *lagopus leucurus*, *centrocercus urophasianus*, *zenaidura macroura*, *circus hudsonius*, *buteo swainsoni*, *falco sparverius*, *asio wilsonianus*, *speotyto cunicularia hypogæa*, *dryobates villosus hyloscopus*, *colaptes auratus*, *otocoris alpestris arenicola*, *xanthocephalus xanthocephalus*, *oroscoptes montanus*, *troglodytes aëdon aztecus*, *parus atricapillus septentrionalis* and *sialia arctica*.

[NOTE. It may seem an anchronism to say that Baird added *d. v. hyloscopus* to the Colorado list, since it was not separated as a variety until many years later. What is meant, of course, is that Baird added the bird which is now called *d. v. hyloscopus*, though he himself used a different name for it.]

1859. **Baird.** In volume ten of the Pacific Railroad Reports, in giving the list of the birds taken by Capt. Gunnison's party, Baird notes specifically as from Colorado, several species that were on hand when volume nine was written, but which are not specially mentioned there as having been taken in Colorado. They are *buteo borealis calurus*, *chordeiles virginianus henryi*, *perisoreus canadensis capitalis*, and *corvus corax sinuatus*.

1870. **Baird.** *Cooper's Birds of California, I.* 1870, *p. 163.* *Leucosticte tephrocotis* taken by Wernigk at Denver.

1872. **Allen.** *Bul. Mus. Comp. Zool. III.* 1872, *pp. 113-183.* The visit of J. A. Allen to Colorado laid the foundation of our knowledge of the birds of the State. Passing across the plains, collecting along the base of the foothills and ascending above timber-line on one of the highest mountains, he presented the first "local list" from Colorado and the first statement of the vertical range of the different species. Mr. Allen's opportunities for observation were neither so good nor so exten-

sive as those of Mr. C. E. Aiken, but his notes being published a few months earlier, makes his records antedate those of Mr. Aiken, though really taken somewhat later. Mr. Allen's list adds 84 species to Colorado birds as follows: *anas strepera, tringa minutilla, totanus melanoleucus, totanus flavipes, totanus solitarius, bartramia longicauda, actitis macularia, ægialitis vocifera, ægialitis montana, bonasa umbellus umbelloides, pediocætes phasianellus campestris, cathartes aura, aquila chrysaëtos, haliæetus leucocephalus, falco peregrinus anatum, ceryle alcyon, picoides americanus dorsalis, sphyrapicus varius nuchalis, sphyrapicus thyroides, melanerpes erythrocephalus, melanerpes torquatus, colaptes cafer, phalænoptilus nuttalli, aëronautes melanoleucus, selasphorus platycercus, tyrannus tyrannus, sayornis saya, contopus borealis, contopus richardsoni, empidonax wrightii, cyanocitta stelleri macrolopha, aphelocoma woodhousei, nucifraga columbianus, molothrus ater, agelaius phœniceus, sturnella magna neglecta, icterus spurius, icterus galbula, icterus bullocki, scolecophagus cyanocephalus, carpodacus cassini, leucosticte australis, spinus tristis, spinus pinus, poocætes gramineus confinis, ammodramus sandwichensis alaudinus, chondestes grammacus strigatus, zonotrichia leucophrys, spizella socialis arizonæ, junco caniceps, melospiza fasciata montana, melospiza lincolni, pipilo maculatus megalonyx, oreospiza chlorura, zamelodia melanocephala, spiza americana, calamospiza melanocorys, piranga ludoviciana, chelidon erythrogastra, tachycineta bicolor, tachycineta thalassina, lanius ludovicianus excubitorides; vireo olivaceus, vireo gilvus, vireo solitarius plumbeus, dendroica æstiva, dendroica auduboni, geothlypis macgillivrayi, icteria virens longicauda, sylvania pusilla, setophaga ruticilla, anthus pensilvanicus, cinclus mexicanus, galeoscoptes carolinensis, harporhynchus rufus, catherpes mexicanus conspersus, sitta carolinensis aculeata, sitta pygmæa, parus gambeli, regulus calendula, myadestes townsendii, turdus fuscescens salicicolus, turdus aonalaschkæ auduboni, sialia mexicana bairdi.*

1872. **Aiken.** *Proc. Bost. Soc. Nat. Hist. XV.* 1872, *pp. 193-210.* For several years, previous to 1872, Mr. C. E. Aiken had been living in Colorado and studying its bird life. His observations were from time to time communicated to Prof. Brewer and Mr. Ridgway. They constitute the largest mass of material on Colorado ornithology collected by any one person. Mr. Aiken's notes, published by Prof. Brewer in 1872, constitute the first records of the movements of the birds in Colorado in winter, and these winter species form, with the water birds, a large part of the 59 species that this list contains in addition to those already given by Mr. Allen. The following are the additions: *hydrochelidon nigra surinamensis, anas boschas, anas americana, anas carolinensis, anas cyanoptera, spatula clypeata, dafila acuta, aix sponsa, aythya vallisneria, aythya affinis, aythya collaris, clangula clangula americana, charitonetta albeola, erismatura jamaicensis, branta canadensis hutchinsii, botaurus lentiginosus, ardea hero-*

dias, grus americana, rallus virginianus, recurvirostra americana, gallinago delicata, tringa maculata, numenius longirostris, bubo virginianus subarcticus, geococcyx californianus, dryobates pubescens homorus, sphyrapicus varius, tyrannus vociferans, myiarchus cinerascens, empidonax traillii, otocoris leucolæma, corvus cryptoleucus, corvus americanus, cyanocephalus cyanocephalus, coccothraustes vespertina, leucosticte tephrocotis, zonotrichia leucophrys intermedia, spizella monticola ochracea, spizella socialis, junco aikeni, junco hyemalis, junco hyemalis connectens, junco mearnsi, pipilo maculatus arcticus, pipilo fuscus mesoleucus, clivicola riparia, ampelis garrulus, ampelis cedrorum, lanius borealis, helminthophila virginiæ, helminthophila celata, compsothlypis americana, dendroica coronata, dendroica nigrescens, geothlypis trichas occidentalis, cistothorus palustris paludicola, parus inornatus griseus, psaltriparus plumbeus, regulus satrapa, sialia sialis.

1873. **Aiken.** *Am. Nat. VII.* 1873, *13*, Mr. Aiken records here *ammodramus bairdi* for Colorado.

1873. **Ridgway.** *Bull. Essex Inst. Nov.* 1873, *179.* This is one of the most important and, at the same time, one of the most unsatisfactory publications ever issued concerning Colorado birds. It gives a list of 243 species known to occur in Colorado, of which 59 had never before been credited to the State. The list is entirely a compilation and much of it from manuscript notes of various persons and collections, yet, for the most of these species, no source of authority is given; for several the source is given incorrectly, and for some it is impossible at this day to ascertain the basis for including them in the list. The list is based largely on the records of Mr. Aiken, and to him belongs most of the credit for the notes on distribution during the breeding season. Many of the species are included on the authority of Mr. Henshaw who had lately taken them and allowed of their publication here in advance of his own notice that appeared at a later date. Several of the rarer species owe a place in the list to their occurrence in the Maxwell collection, a complete list of which was not published until 1877. And, as stated above, there are some species whose source cannot be now ascertained. The following species appear in this list for the first time; those marked with one star having been taken by Mr. Aiken, those with two stars by Mr. Henshaw, and those with the asterisk are in the Maxwell Collection. ***Colymbus nigricollis californicus, †podilymbus podiceps, †urinator imber, †larus delawarensis, sterna forsteri, †pelecanus erythrorhynchos, †merganser americanus, †lophodytes cucullatus, *anas obscura, aythya marila nearctica, †branta canadensis, olor buccinator, †plegadis guarauna, †ardea candidissima, †porzana carolina, **fulica americana, †steganopus tricolor, **tringa bairdii, †tringa alpina pacifica, **ereunetes pusillus, **symphemia*

semipalmata inornata, *charadrius dominicus*, **meleagris gallopavo*, *accipiter velox*, *accipiter cooperi*, *accipiter atricapillus*, *archibuteo lagopus sancti-johannis*, ***archibuteo ferrugineus*, ***falco mexicanus*, *falco columbarius*, *falco richardsoni*, †*pandion haliaëtus carolinensis*, **glaucidium gnoma*, **melanerpes carolinus*, *trochilus alexandri*, ***empidonax difficilis*, ***empidonax minimus*, ***empidonax hammondi*, ***dolichonyx oryzivorus*, ***quiscalus quiscula æneus*, †*pinicola enucleator*, *loxia curvirostra stricklandi*, †*plectrophenax nivalis*, †*calcarius ornatus*, †*rhynchophanes mccownii*, *ammodramus savannarum perpallidus*, †*spizella pallida*, ***spizella breweri*, *amphispiza bilineata*, *amphispiza belli nevadensis*, *passerella iliaca schistacea*, **guiraca cærulea eurhyncha*, **passerina cyanea*, ***progne subis*, ***stelgidopteryx serripennis*, **helminthophila peregrina*, *troglodytes hiemalis*, *certhia familiaris montana*, **polioptila cærulea*, †*turdus ustulatus swainsonii*.

1874. **Ridgway.** *Am. Sportsman, IV.* 1874, *241*. Records *leucosticte atrata* taken by Aiken at Colorado Springs.

1874. **Coues.** *Birds of the Northwest.* In addition to a recapitulation of what has been written by Allen and Aiken on Colorado birds, this book contains some long and valuable notes by T. M. Trippe on the birds of Idaho Springs and vicinity. Also several extended notes by J. A. Allen, supplementary to those he had already published. There is here published the first and only record of the species taken by Stevenson during the trip made by Dr. Hayden's party in 1869. This party started at Cheyenne, passed south to Denver, up Clear Creek and over Berthoud's Pass to Middle Park, back to Denver and south via Colorado City and Trinidad to New Mexico. The first records for Colorado given in Birds of the Northwest are *phalaropus lobatus*, *acanthis linaria* and *seiurus aurocapillus*.

1874. **Baird, Brewer** and **Ridgway.** *History of North American Birds.* *Icteria virens* taken by Thos. Say near the headwaters of the Arkansas.

1876. **Henshaw.** *Surveys West of One Hundredth Meridian, Vol. V.* Though some of these notes were really published two years previous, it will be better for present purposes to refer to the above which is the complete report of Mr. Henshaw's work.

In 1873 Henshaw and his assistants visted Denver and after a prolonged stay there during May, visited the San Luis Valley, making their headquarters at Fort Garland. The next year C. E. Aiken, as assistant ornithologist of the party, collected in the vicinity of Colorado Springs and Pueblo and then crossing the range into San Luis Park collected as far west as

Pagosa Springs. In addition to the species communicated to Mr. Ridgway and published by him in 1873, the following are given: *chen hyperborea*, *himantopus mexicanus*, *macrorhampus scolopaceus*, *limosa fedoa*, *selasphorus rufus*, *spinus psaltria arizonæ*, *pipilo aberti*, *piranga rubra cooperi*, *dendroica maculosa*, *dendroica rara*, *dendroica striata*, *dendroica townsendi*, *seiurus noveboracensis notabilis*, *sitta canadensis*.

1877. **Ridgway.** *Maxwell's Colorado Museum. Field and Forest*, *II.* 1876-7, *pp. 195 and 208.* This is the finest collection ever made of Colorado birds. It has been claimed that every bird in this collection was actually taken in Colorado. There seems good and sufficient reasons for believing that some of the skins bought by Mrs. Maxwell were really taken outside the State. They were all mounted by Mrs. Maxwell and largely collected by her. Most of them were taken in the vicinity of Boulder, but many were sent to her by friends in other parts of the State. Unfortunately nearly all of the data accompanying these specimens have been lost and there is now no means of ascertaining when or where they were captured.

Besides the species already given from this collection in Ridgway's List there are the following: *stercorarius parasiticus*, *rissa tridactyla*, *larus philadelphia*, *xema sabinii*, *phalacrocorax dilophus*, *mergus serrator*, *clangula islandica*, *oidemia americana*, *anser albifrons gambeli*, *olor columbianus*, *tantalus loculator*, *nycticorax violaceus*, *charadrius squatarola*, *asio accipitrinus*, *nyctala acadica*, *megascops asio maxwelliæ*, *megascops flammeola*, *coccyzus americanus occidentalis*, *leucosticte tephrocotis littoralis*, *calcarius lapponicus*, *vireo solitarius cassinii*. Two of these, *rissa tridactyla*, and *nycticorax violaceus*, still remain the first and only records for Colorado.

This completes the record of all work done in Colorado by the government surveying parties and by the individual workers that did so much for the ornithology of the state from 1869 to 1876. The state list at this time numbered 279 species or two more than those included ten years later by Mr. Drew in his list of Colorado birds. The Maxwell collection is the last large addition to the Colorado list. The 81 species that have since been added are nearly all rare or accidental visitants and have been added a few at a time by a large number of different workers.

1877. **Coues.** *B. N. O. C. II.* 1877, *pp. 50 and 83.* Adds *conurus carolinensis* and *melopelia leucoptera* taken by E. L. Berthoud.

1880. **Minot.** *B. N. O. C. V.* 1880, *223.* First record for *mniotilta varia* and the first and only record for *saxicola œnanthe*, taken at Boulder.

1881. **Drew.** *B. N. O. C. VI.* 1881, *pp. 85 and 138.* The government expeditions under Mr. Henshaw extended over much of southern Colorado and their work is supplemented by that of Mr. Drew, which gives us the results of several years' active field work in the extreme southwest corner of the State. Several new species are added as follows: *histrionicus histrionicus, ceophlœus pileatus, cypseloides niger borealis, loxia leucoptera, dendroica graciæ* and *merula migratoria propinqua.*

1883. **Brewster.** *B. N. O. C. VIII.* 1883, *57.* Records the capture of *harporhynchus bendirei* at Colorado Springs.

1883. **Allen & Brewster.** *B. N. O. C. VIII.* 1883, *151 and 189.* *Gallinula galeata* taken at Colorado Springs.

1884. **Ridgway.** *Auk, I.* 1884, *50.* *Buteo borealis harlani* taken by Aiken at Colorado Springs.

1885. **Drew.** *Auk, II.* 1885, *11.* Includes *colymbus holbœllii* but gives no authority for the record. Also mentions that *colinus virginianus* and *callipepla californica* have been introduced in the State. Includes *cardinalis cardinalis* probably based on Anthony's specimen at Denver.

1885. **Beckham.** *Auk, II.* 1885, *139.* *Numenius hudsonicus* and *thryothorus bewickii leucogaster* taken at Pueblo.

1886. **H. G. Smith.** *Auk, III.* 1886, *284.* Records *larus argentatus smithsonianus, nycticorax nycticorax nævius, philohela minor* and *scolecophagus carolinus* from near Denver, and *syrnium occidentale* as taken by C. E. Aiken near Colorado Springs.

1887. **Beckham.** *Auk, IV.* 1887, *120.* *Zonotrichia querula* and *zonotrichia albicollis* taken at Pueblo.

1887. **Thorne.** *Auk, IV.* 1887, *264.* *Branta bernicla, grus canadensis* and *micropalama himantopus* taken by him at Fort Lyon.

1887. **Dille.** *O. & O. XII.* 1887, *97.* *Buteo borealis krideri* taken in Weld County.

1887. **Ridgway.** *Manual of North American Birds.* *Helminthophila celata lutescens* noted as occurring in Colorado.

1888. **Morrison.** *O. & O. XIII.* 1888, *pp. 70, 107, 115 and 139.* *Meleagris gallopavo mexicana* added from La Plata County.

1888. **Morrison.** *O. & O. XIII.* 1888, *pp. 145, 165 and 181, XIV.* 1889, *pp. 6, 65 and 145. XV.* 1890, *p. 36.* *Ajaja ajaja* taken at Silverton, *tringa fuscicollis* taken by Capt. Thorne at Fort Lyon, *callipepla gambeli* taken by Mr. Morrison in southwestern Colorado, *nyctea nyctea* and *junco phæonotus dorsalis.*

1888. **Thorne.** *Auk, V.* 1888, *p. 112. Turdus aonalaschkæ pallasii* from Fort Lyon.

1889. **Thorne.** *Auk, VI.* 1889, *276. Myiarchus lawrencei olivascens* and *sayornis phœbe* taken by him at Fort Lyon.

1890. **Kellogg.** *Trans. Kans. Acad. Science, XII.* 1889–90, *86. Sitta carolinensis* taken by him in Estes Park.

1891. **Brewster.** *Auk, VIII.* 1891, *139.* Description of *megascops asio aikeni*, the type taken by Aiken at Colorado Springs.

1893. **McGregor.** *Auk, X.* 1893, *205. Junco annectens* taken near Boulder.

1893. **Osburn.** *Science, XXII.* 1893, *212. Accipiter atricapillus* and *zonotrichia coronata* taken at Loveland.

1894. **Cooke.** *Auk, XI.* 1894, *182. Ardetta exilis*, at Colorado Springs; *oidemia deglandi, calidris arenaria* and *coccyzus erythrophthalmus*, in the museum of the Agricultural College, at Fort Collins.

1894. **Lowe.** *Auk, XI.* 1894, *324. Guara rubra* taken in the Wet Mountains near Pueblo in May, 1876.

1895. **Deane.** *Auk, XII.* 1895, *292. Harelda hyemalis* taken near Denver.

1895. **Lowe.** *Auk, XII.* 1895, *298. Callipepla squamata* taken by him in the Wet Mountains.

1895. **Lowe.** *Nidologist, II.* 1894-5, *99. Passer domesticus* first seen at Pueblo, February, 1895.

1896. **Bendire.** *Life Histories of North American Birds. Part II. Coccyzus americanus, dryobates pubescens* and *phalænoptilus nuttalli nitidus* are credited to Colorado, but no authority given.

1896. **Smith.** *Nidologist, III.* 1895-6, *48, 65 and 76. Æchmophorus occidentalis, larus atricilla, sterna paradisæa, oidemia perspicillata, guara alba, arenaria interpres, strix pratincola, dendroica cærulescens* and *turdus aonalaschkæ* all taken in the vicinity of Denver.

1897. **Cooke.** *Colorado Experiment Station Bulletin No. 37.* The present publication contains the first records for Colorado of several species as follows: *ardea rufescens, elanoides forficatus* and *bubo virginianus arcticus*, by Aiken; *carpodacus purpureus*, by Anthony; *ictinia mississippiensis, buteo lineatus elegans, milvulus forficatus* and *sylvania pusilla pileolata*, by Breninger; *dryobates*

scalaris bairdi, by Lowe; *larus californicus*, *larus occidentalis*, *larus franklinii*, *ereunetes occidentalis* and *ægialitis semipalmata*, by Osburn; *chen hyperborea nivalis* and *megascops asio*, by Snyder; *colymbus auritus*, *melospiza fasciata* and *dendroica æstiva sonorana*, by Thorne.

RECAPITULATION.

DATE	AUTHORITY.	Number of Species added	Total number of Species to date
1823	Thos. Say	11	11
1858	S. F. Baird	19	30
1859	S. F. Baird	4	34
1870	S. F. Baird	1	35
1872	J. A. Allen	84	119
1872	C. E. Aiken	59	178
1873	C. E. Aiken	1	179
1873	R. Ridgway	60	239
1874	R. Ridgway	1	240
1874	E. Coues	3	243
1874	Baird, Brewer and Ridgway	1	244
1876	H. W. Henshaw	14	258
1877	R. Ridgway	21	279
1877	E. Coues	2	281
1880	H. D. Minott	2	283
1881	F. M. Drew	6	289
1883	Wm. Brewster	1	290
1883	Allen and Brewster	1	291
1884	R. Ridgway	1	292
1885	F. M. Drew	4	296
1885	C. W. Beckham	2	298
1886	H. G. Smith	5	303
1887	C. W. Beckham	2	305
1887	P. M. Thorne	3	308
1887	F. M. Dille	1	309
1887	R. Ridgway	1	310
1888	C. F. Morrison	1	311
1888	C. F. Morrison	5	316
1888	P. M. Thorne	1	317
1889	P. M. Thorne	2	319
1890	V. L. Kellogg	1	320
1891	Wm. Brewster	1	221
1893	R. C. McGregor	1	322
1893	Wm. Osburn	2	324
1894	W. W. Cooke	4	328
1894	W. P. Lowe	1	329
1895	R. Deane	1	330
1895	W. P. Lowe	1	331
1895	W. P. Lowe	1	332
1896	C. Bendire	3	335
1896	H. G. Smith	9	344
1897	W. W. Cooke	19	363

THE BIRDS OF COLORADO.

1. **Æchmophorus occidentalis.** WESTERN GREBE.

Migratory; rare. A western species that finds its eastern limit at the western edge of the plains. The only certain record for the State is that of H. G. Smith (Nidologist, III. 1896, 48) who saw the skins of one that had been shot near Denver about October 25, 1888, and of two others taken in the vicinity a few days earlier. It may eventually be found to breed in Colorado, since it is an abundant summer resident in Utah.

2. **Colymbus holbœllii.** HOLBŒLL'S GREBE.

Migratory; rare; a northern species coming south in the winter. It is a widely distributed species, liable to be found anywhere but so far has been noted in Colorado only in the southwestern corner in La Plata County, where F. M. Drew noted it in the autumn at 10,000 feet (Auk, II. 1885, 11) and C. F. Morrison notes it as "rare" in the same locality (O. & O. XIII. 1888, 70). It breeds far north.

3. **Colymbus auritus.** HORNED GREBE.

Migratory; rare. Inhabits the whole of North America, but its only Colorado record is that of Capt. P. M. Thorne who writes, "I find in my journal under date of October 8, 1887, the following. 'Killed a *C. auritus.* Was alone. Not seen here before.' I do not think a mistake as to identification possible. I am familiar with *C. n. californicus* and *P. podiceps.*" This was at Ft. Lyon on the Arkansas River. The Horned Grebe breeds from the northern United States northward and comes south in the winter.

4. **Colymbus nigricollis californicus.** AMERICAN EARED GREBE.

Summer resident; rare in eastern, not uncommon in western Colorado; breeds in suitable localities throughout its range from the plains to 8,000 feet, especially on the alkali lakes. Mr. Henshaw found it nesting abundantly in the San Luis Valley, most of the eggs being fresh June 23. He also found the birds quite numerous in migration at Denver as late

as May 15, 1874. Its nest has been taken at Loveland, with fresh eggs June 20, and it is not uncommon on the lakes and reservoirs in the Big Thompson and Cache La Poudre Valleys. A few pass across the State and enter Kansas.

6. **Podilymbus podiceps.** PIED-BILLED GREBE.

Summer resident, rare; in migration, common. The only records of breeding come from the vicinity of Loveland, though it probably will be found breeding over much of the northern third of the State below 7,000 feet. In the southern portion of Colorado it is known only as a migrant, but in open seasons a few may remain through the winter.

7. **Urinator imber.** LOON.

Found throughout the State as a migrant and occasionally in winter, but not so common as in most of the country farther east. It has not been known to breed in Colorado, and probably all leave the State for their northern breeding grounds.

37. **Stercorarius parasiticus.** PARASITIC JAEGER.

Breeds at the far north and comes south to Colorado as a rare visitant in fall and winter. Three cases have been recorded. One, in Mrs. Maxwell's collection, was taken at Boulder in December, some time previous to 1874. A young bird in the dark phase was shot at Sloan's lake near Denver during the fall of 1889. (H. G. Smith, Nidologist, III. 1896, 48.)

Mr. W. P. Lowe, of Pueblo, writes that one was secured on the Arkansas River a mile below Pueblo in the fall of 1894, and is now in his collection.

40. **Rissa tridactyla.** KITTIWAKE.

A northern species, rare or accidental in Colorado in the winter. The only known specimen is the one in Mrs. Maxwell's collection, which was taken at Boulder in December.

49. **Larus occidentalis.** WESTERN GULL.

A Pacific Coast bird; accidental in Colorado. The only record for the State is the one Prof. Wm. Osburn writes that he took at Loveland, September 30, 1889.

51a. **Larus argentatus smithsonianus.** AMERICAN HERRING GULL.

Inhabits the whole of North America and occurs rarely in Colorado during migration. One was seen for several days by Mr. Breninger, near Fort Collins, and a young bird was shot at Denver, November 17, 1883. (Auk, III. 1886, 284.)

53. **Larus californicus.** CALIFORNIA GULL.

A western species that has been found breeding in immense numbers in Utah and has also been once taken in Kansas. It

would be supposed then that it would be not uncommon in Colorado and it may yet be found rarely in the western part of the State, or even breeding, but at present the only record for Colorado is the one taken by Prof. Wm. Osburn, at Loveland, May 7, 1890.

54. **Larus delawarensis.** RING-BILLED GULL.

Summer resident, rare; in migration, common. The only gull that is commonly found throughout Colorado. Many are seen in the spring migration and they are very common in autumn on all bodies of water below 9,000 feet. They migrate early, appearing in southern Colorado by the middle of March. F. M. Drew records it as breeding at 6,000 feet. (Auk, II. 1885, 11.)

58. **Larus atricilla.** LAUGHING GULL.

A gull of the South Atlantic and Gulf States accidental once in Colorado. One was shot at Sloan's Lake near Denver in December, 1889. (H. G. Smith, Nidologist, III. 1896, 48.)

59. **Larus franklinii.** FRANKLIN'S GULL.

Migratory; rare. Has been taken by Wm. G. Smith, at Loveland, and A. W. Anthony saw a freshly mounted specimen said to have been taken near Denver.

60. **Larus philadelphia.** BONAPARTE'S GULL.

Migratory; rare. Eight specimens have been recorded, and every one has been taken along the edge of the plains from Colorado Springs to Fort Collins. Nearly all were captured in the fall, when it is reported as not uncommon in some localities.

62. **Xema sabinii.** SABINE'S GULL.

Winter visitant; rare. Breeds far north and comes south for the winter. Five occurrences have been recorded, all in the fall and early winter from October to December. They were noted at Denver, Boulder, Loveland and Fort Collins.

69. **Sterna forsteri.** FORSTER'S TERN.

Summer resident, rare; in migration, not uncommon. According to Mr. Ridgway a few breed in the State (Bull. Essex Institute, V. Nov. 1873, 174), but most of them are merely migrants. They are almost as common in the spring as in the fall. They reach northern Colorado the last of April and early in May.

71. **Sterna paradisæa.** ARCTIC TERN.

Migratory; very rare. But two instances are on record. Prof. Wm. Osburn has an adult male that was shot at Loveland,

July 9, 1889, and Mr. Ridgway has identified for H. G. Smith one that was shot near Denver in the spring of 1887. (Nidologist, III. 1896, 48.)

[74. **Sterna antillarum.** LEAST TERN.

In the Auk, XI. 1894, 182, the present writer added this to the list of Colorado birds on the strength of a mounted specimen at Colorado Springs that he was told had been taken in that vicinity. Further investigation has convinced him that the specimen was secured outside of Colorado. There is now no certain record for this State. It is a southern species that breeds as far north as Kansas, and will undoubtedly some day be obtained in Colorado.]

77. **Hydrochelidon nigra surinamensis.** BLACK TERN.

Summer resident; not uncommon; in a few localities, nests quite abundantly; somewhat more common in migration. It is found on both sides of the range almost anywhere that the natural conditions are suitable. Reaches northern Colorado the middle of May.

120. **Phalacrocorax dilophus.** DOUBLE-CRESTED CORMORANT.

All the records for Colorado come from the eastern foothills. There was one in Mrs. Maxwell's collection and H. G. Smith records four instances near Denver; one about November 1, 1885, one about October 1, 1891, from a flock of about 20, one in the fall of 1886, and a fourth from Jones' Lake, near Denver. (Auk, III. 1886, 284, and Nidologist, III. 1896, 48.) Since it has been found breeding abundantly in Utah, it will probably yet be found in the western half of Colorado.

125. **Pelecanus erythrorhynchos.** AMERICAN WHITE PELICAN.

Formerly not uncommon in migration and some remained to breed; now rare in migration and no late record of its breeding. It is still occasionally noted from both sides of the range. Has been taken in the San Luis valley in October, 1887, at 8,000 feet, but usually is found below 5,500 feet. Still breeds in Wyoming and Montana. Passes across Colorado late in April and early in May.

129. **Merganser americanus.** AMERICAN MERGANSER.

Resident; winter sojourner not uncommon; rather more common in migration; breeds along the northern boundary of the United States and northward and a few breed in the mountains and mountain parks of the north half of Colorado. It is found in winter wherever there is open water along the South Platte, especially near Fort Morgan, and is likely to be noted on any open water on the plains. It is most common in April, moving northward. It has been reported less commonly from the western half of Colorado, but as it is of general distribution in North America, it probably occurs throughout the State.

130. **Merganser serrator.** RED-BREASTED MERGANSER.

Winter sojourner, rare; in migration, not uncommon. Breeds far north. Occurs in winter on the Platte, and in migration throughout the plains district of eastern Colorado. Undoubtedly occurs, though not yet reported, on the lower waters of western Colorado.

131. **Lophodytes cucullatus.** HOODED MERGANSER.

Resident; a few remain in the State during the winter, and a still smaller number nest irregularly over eastern Colorado and in the mountains. It is a little more common in migration, especially late in the fall, just before the lakes freeze. Capt. Thorne found it at Fort Lyon on June 20 and July 2.

132. **Anas boschas.** MALLARD.

Resident; in winter, not uncommon; in migration, one of the most common ducks, especially in the fall; breeds throughout the State below 9,000 feet, on the plains as well as among the mountains. Chas. F. Morrison makes the statement that in La Plata County the Mallards are never seen in the fall (O. & O. XIII. 1888, 70), however in the lower portions of the State they are abundant at that season, and they have been known to ascend to 10,500 feet during the autumn. The larger part of migration takes place in March, and by the latter part of April few are left except those that remain to breed.

133. **Anas obscura.** BLACK DUCK.

Migratory; rare. An eastern species finding in Colorado its most western extension. One was taken by C. E. Aiken prior to 1873 (Ridgway, Bull. Essex Institute, V. 174), and Prof. Wm. Osburn writes that he took one on the Big Thompson, near Loveland, March 15, 1889.

135. **Anas strepera.** GADWALL.

Summer resident, not common; in migration, common. C. F. Morrison says: "It breeds in the sloughs and small lakes at 11,000 feet in southwestern Colorado. I secured ten young from the La Plata River, unable to fly. These with the parent birds came down from the mountains. They started quite young on their southern migration." (O. & O. XIII. 1888, 145.) V. L. Kellogg found them breeding in Estes Park. (Trans. Kans. Acad. Science, VII. 1889-90, 86.) Other observers have noted their breeding on the plains. It is never as common in migration as many of the other ducks, but old hunters expect to get a few each season. They are most common during the spring migration early in March.

137. **Anas americana.** BALDPATE.

Summer resident; tolerably common, locally; in migration, commonly distributed all over the State and occasionally in the fall migration is locally abundant. Breeds mostly in the north, but a few remain behind to breed on the prairies of Kansas and eastern Colorado, while Dr. Coues found them breeding in large numbers in North Park at an altitude of about 8,000 feet. (B. N. O. C. II. 1877, 51.)

139. **Anas carolinensis.** GREEN-WINGED TEAL.

Summer resident; common, locally; in migration, abundant. One of the earliest ducks to migrate in the spring and on the plains one of the most abundant. The bulk breed farther north and it is a rare breeder on the plains, but among the mountains and mountain parks it is not uncommon through the summer. Henshaw found it in the San Luis Valley breeding in considerable numbers June 24, but not yet through laying. Morrison reports its breeding near Fort Lewis in southwestern Colorado, and Kellogg found it as a common summer resident of Estes Park.

140. **Anas discors.** BLUE-WINGED TEAL.

Summer resident, common; in migration, abundant. Whatever has been given above concerning the Green-winged Teal would apply equally to the Blue-winged.

141. **Anas cyanoptera.** CINNAMON TEAL.

Summer resident; common. A western species abundant over all the country west of the Rocky Mountains. Many cross the range and are found along the eastern foothills; farther east they are rare. H. G. Hoskins writes that he found one at Beloit, near the eastern boundary of the state, on October 27, 1895, and they have several times been taken in Kansas. There is no record of their breeding far out on the plains of Colorado, but judging from their known habits it is probable that a few breed locally over much of the country from the mountains to Kansas. In north central Colorado, at the western edge of the plains, a scattered pair or two can be found breeding in most of the sloughs or marshes. West of the range, Henshaw found them breeding in southern Colorado in June and Dr. Coues notes them as very abundant breeding at small lakes in North Park. They are among the later migrants of the ducks arriving in northern Colorado early in April, and by the middle of June have full clutches of eggs.

142. **Spatula clypeata.** SHOVELLER.

Summer resident; common, locally; in migration, abundant. This duck inhabits the whole of North America and is

among the few that breed throughout their range. It has been taken all over Colorado, but apparently is more common as a breeder in the western half, not because it is more common there in migration, but it seems to prefer the higher altitude. Records of its breeding on the plains are not numerous, but in the mountain parks at about 8,000 feet it is one of the most numerous of the summer resident ducks.

143. **Dafila acuta.** PINTAIL.

Summer resident; rare; in migration, common; winter resident, rare. Some days during spring and fall migration this duck is very common on the plains. It is a bird of the plains, seldom going above 6,000 feet. A few remain around open water on the plains through the winter. It was recorded several years ago as breeding in the State (Ridgway, Bull. Essex Inst. V. 1873, 174), though it usually breeds from the northern row of states in the United States northward. Both W. G. Smith and G. F. Breninger write that it breeds in Larimer County, east of the foothills.

144. **Aix sponsa.** WOOD DUCK.

Summer resident; rare. Occurs over all of the United States and breeds throughout its range, but it must be considered as one of the rare ducks in Colorado. It has been taken at Loveland and is occasionally taken on the lakes near Denver. C. F. Morrison says, "I found this duck at Fort Lewis, where it no doubt breeds, although I found no nest. Abundant about the headwaters of the Rio La Plata at an elevation of 9,500 feet." (O. & O. XIII. 1888, 165.)

146. **Aythya americana.** REDHEAD.

Migratory; common. Breeds far north. Is more common in Colorado than the Canvas-back and occurs throughout the State. Is one of the earlier ducks to move in the spring and occasionally a few appear in the fall by the middle of September, sometime before the regular flight begins.

147. **Aythya vallisneria.** CANVAS-BACK.

Migratory; not common. A few are observed spring and fall over all of the State, and sometimes quite large flocks are noted. It lingers late in the fall and has even been noted in the winter on the plains. Breeds far north.

148. **Aythya marila nearctica.** AMERICAN SCAUP DUCK.

Migratory; rare. Occurs on both sides of the range, but never common anywhere. Has been seen as late as December in southwestern Colorado at 9,000 feet. (Drew, B. N. O. C. VI. 1881, 85.) Breeds far north.

149. **Aythya affinis.** LESSER SCAUP DUCK.

Migratory; not common. Its range is much the same as the last species, but it is rather more common. Occasionally found in southern Colorado in winter. Reaches northern Colorado early in March.

150. **Aythya collaris.** RING-NECKED DUCK.

Migratory; rare. It is a little strange that this duck should be so uncommon as it seems to be in Colorado, since it is more common in Kansas than either of the others. Probably occurs on both sides of the range, though all the records are on the plains east of the foothills. Breeds far north.

151. **Clangula clangula americana.** AMERICAN GOLDEN-EYE.

Migratory; rare. Occurs throughout the State, but never common. Breeds far north, but begins to migrate early. C. E. Aiken took one in southern Colorado at 9,000 feet on August 30, 1874.

152. **Clangula Islandica.** BARROW'S GOLDEN-EYE.

Resident; not common. The distribution of Barrow's Golden-eye in Colorado is rather strange. It is a northern species, coming south in the winter to Colorado, and then when spring returns quite a share of these winter birds remain to breed in the mountains. So there results the queer condition of a northern species breeding in the mountains almost at the extreme southern limit of its range. On the plains it is a rare migrant and winter visitant; in the mountains it has been found breeding throughout the whole western half of Colorado, usually at about 8,000 feet. Chas. F. Morrison has the following note concerning its occurrence: "This species might almost be called a resident in southwestern Colorado. I can record its breeding in Dolores County, and have taken them all through the winter in the ponds below Fort Lewis." (O. & O. XIII. 1888, 165.) It nests in trees. There are no records of its extending much east of the mountains far out on the plains, and it never has been taken in Kansas.

153. **Charitonetta albeola.** BUFFLE-HEAD.

Migratory; common. Occurs throughout the State in migration, and is likely to be found near any open water in the winter. Breeds far north.

154. **Harelda hyemalis.** OLD-SQUAW.

Winter visitant; rare. A northern species coming south into Colorado in the late fall and winter. The only records come from the north central part of the state where G. F. Breninger writes that he found a dead bird on the shore of one

of the lakes near Fort Collins. J. B. Sibley shot a male and female on McKay Lake near Denver, November 13, 1892. (Deane, Auk, XII. 1895, 292.)

155. **Histrionicus histrionicus.** HARLEQUIN DUCK.

Resident; not common. This is regularly a northern species, breeding far north and coming into Colorado in the winter as it does over the Mississippi Valley to the eastward. But a few remain to breed at about 10,000 feet in the mountains more particularly of western Colorado. C. F. Morrison says: "I believe it breeds in both the San Juan and La Plata counties. * * * I have often seen it through the winter below Fort Lewis on the Ute reservation together with *G. islandica.*" (O. & O. XIII. 1888, 165.) F. M. Drew gives it as breeding from 7,000 to 10,000 feet. (Auk, II. 1885, 11.)

163 **Oidemia americana.** AMERICAN SCOTER.

Winter visitant; rare. This and the next two are "Surf Ducks" that breed far north and come south in the winter, principally along the coast, but a few visit the larger inland waters. One would suppose them out of place in arid Colorado, but professional hunters expect to see a few of them each year. An American Scoter is in Mrs. Maxwell's collection and G. F. Breninger writes that he found a dead one near Fort Collins.

165. **Oidemia deglandi.** WHITE-WINGED SCOTER.

Winter visitant; rare. G. F. Breninger reports the capture of three specimens, one of which, taken November 3, 1890, is now in the cabinet of the State Agricultural College at Fort Collins. H. G. Smith reports four specimens as follows: one at Marston's Lake, near Denver, October, 1887; one on Lee's Lake, near Fort Collins, October 23, 1888; one taken by Wm. G. Smith, at Loveland; one at Sloan's Lake, near Denver, October 16, 1890. (Nidologist, III. 1896, 48.)

166. **Oidemia perspicillata.** SURF SCOTER.

Winter visitant; rare. Prof. Wm. Osburn writes that he saw one in the collection of Wm. G. Smith, taken at Loveland. H. G. Smith says that one was taken at Marston's Lake, near Denver, October, 1887, in company with the specimen of *O. deglandi* mentioned above. (Nidologist, III. 1896, 48.)

167. **Erismatura jamaicensis.** RUDDY DUCK.

Summer resident; common. Occurs on both sides of the range in migration and during the breeding season is not uncommon in the mountains up to 10,000 feet. East from the mountains it becomes less common in summer until along the

eastern border of Colorado it rarely nests, though still common in migration. It is rather late to arrive in the spring and the eggs are laid by the middle of June.

169. **Chen hyperborea.** LESSER SNOW GOOSE.

Migrant and winter resident; not common. A few are seen during migration spring and fall along the plains east of the mountains. There is no record of their wintering on the plains though probably they are at least an occasional winter visitant to the open waters of southeastern Colorado. Twenty years ago Henshaw heard of them as wintering abundantly in the San Luis Valley. But they are much less common everywhere in the Rocky Mountain region now than they were then. West and southwest of Colorado they still remain fairly abundant. Breeds far north.

169a. **Chen hyperborea nivalis.** GREATER SNOW GOOSE.

Migratory; rare. The eastern form, not coming regularly as far west as Colorado, being confined mostly to the Atlantic coast. A specimen shot by Pres. Z. X. Snyder east of Greeley, March 20, 1895, is a little longer than the greatest length given for the Greater Snow Goose. This is the only certain Colorado record.

171a. **Anser albifrons gambeli.** AMERICAN WHITE-FRONTED GOOSE.

Migratory; rare. Probably the rarest Goose that regularly occurs in Colorado. A few have been taken in migration in eastern Colorado.

172. **Branta canadensis.** CANADA GOOSE.

Summer resident, rare except locally; winter resident, not common; in migration, common. The most common Goose of the State. It might almost be called resident since there is no time in the year when there are not some in the State, but it is probable that the same individuals do not remain here throughout the year, those that breed in Colorado going farther south for the winter and their places being taken by those that nested further north. On the plains of eastern Colorado they are known only as migrants and winter residents. In the mountains they breed along the higher secluded lakes at about 10,000 feet, especially in North Park, where Dr. Coues found them breeding in large numbers. (B. N. O. C. II. 1887, 51.) A few remain in southern Colorado through the winter and they are likely to appear irregularly anywhere east of the range except in the severest weather.

172a. **Branta canadensis hutchinsii.** HUTCHINS'S GOOSE.

Migratory; common. Not quite so common as the Canada Goose and breeding only north of the United States. Passes through in migration spring and fall and a few may winter, since it has been taken as late as December.

173. **Branta bernicla.** BRANT.

Migratory; rare or accidental. An eastern species seldom coming so far west as Colorado. A specimen was shot by Capt. P. M. Thorne at Fort Lyon, April 11, 1883, and though it was not preserved there can scarcely be any doubt of the correctness of the identification.

180. **Olor columbianus.** WHISTLING SWAN.

Migratory; not common. In former years Swans were fairly common over much of western North America. Now they are rare anywhere but are still found in migration in Colorado. H. G. Smith mentions four cases of the occurrence of the Whistling Swan at various places in eastern Colorado and says he has heard of others. (Nidologist, III. 1896, 48.) One was shot from a flock of three at Fort Collins, March 16, 1895 and preserved by a local taxidermist.

181. **Olor buccinator.** TRUMPETER SWAN.

Migratory; rare. Apparently not so common as the last species. There was a specimen in the Maxwell collection and H. G. Smith reports two instances that have come to his knowledge. It has never been known to breed in Colorado, though breeding but a little farther north in the Mississippi Valley. One was shot during the fall of 1896 near Fort Collins.

183. **Ajaja ajaja.** ROSEATE SPOONBILL.

Accidental visitant; two instances. A southern species not regularly occurring north of the Gulf States. In a letter dated June 17, 1888, T. M. Trippe, of Howardsville, Colo., writes to C. F. Morrison, as follows: "A Rosy Spoonbill was captured at Silverton, Colo., the other day. It was caught alive, but died in a day or two. It was a female in fine spring plumage." (O. & O. XIII. 1888, 181.) H. G. Smith notes a specimen in very worn plumage August 8, 1890. Said to have been taken near Pueblo. (Nidologist, III. 1896, 65.)

184. **Guara alba.** WHITE IBIS.

Migratory; rare. A southern species, but once known to have been taken in Colorado, but since it has been taken at Great Salt Lake to the west and up the Mississippi Valley to South Dakota, its occurrence in Colorado may not be acci-

dental. The only record for Colorado is the one noted by H. G. Smith that was shot in 1890 at Barr Lake, east of Denver. (Nidologist, III. 1896, 65.)

[185.] **Guara rubra.** SCARLET IBIS.

Accidental. A tropical species that is recorded but four times from the United States. The first three were found, one each, in Florida, Louisiana and Texas; the fourth and last in Colorado. A finely plumaged adult male was shot in the Wet Mountains, May, 1876. The mounted bird is still in the possession of Mr. Livesey, who until 1894 resided in Pueblo. This is the most wonderful record in the whole list of Colorado birds, but there is no doubt whatever of its correctness.

187. **Plegadis guarauna.** WHITE-FACED GLOSSY IBIS.

Summer visitant; rare. Though fairly common locally in New Mexico and Arizona, the Ibis seldom goes as far north as Colorado. H. G. Smith says that it is occasionally reported by sportsmen. He has examined three specimens from Marston's Lake, near Denver, and one from Pueblo. Other specimens have been purchased in the Denver market. (Nidologist, III. 1896, 65.) P. B. Peabody reports one purchased at Colorado Springs and killed in that vicinity. (Nidologist, II. 1895, 116.) There was a specimen in the Maxwell collection, and Prof. Wm. Osburn writes that Wm. G. Smith of Loveland had one in his collection. From its occurrence in Colorado in the summer Mr. Ridgway concludes that it breeds in the State in the "marshes of valleys." (Bull. Essex Institute, V. 1873, 174). The present writer knows of no nests that have ever been taken in Colorado.

188. **Tantalus loculator.** WOOD IBIS.

Summer visitant; rare. There was a mounted specimen of this southern species in the Maxwell collection and this seems to be the basis for the earlier references to its occurrence in Colorado. When and where this specimen was taken can not now be learned. There seems to be no authentic basis for a certain published statement that it breeds in Colorado, except the well-known fact that it ordinarily breeds throughout its range. Mr. C. E. Aiken informs the present writer that he knows of two specimens that have been taken in Colorado.

190. **Botaurus lentiginosus.** AMERICAN BITTERN.

Summer resident; common. Occurs throughout the State, breeding from the plains to about 7,000 feet. Arrives late in April and begins laying by the middle of May.

191. **Ardetta exilis.** LEAST BITTERN.

Summer visitant; rare. The only record for Colorado is a stuffed specimen now at Colorado Springs that was killed in the immediate vicinity. It is a little strange that no more is known of this bird in Colorado. It is a common bird in Kansas and extends clear across to the Pacific Ocean, though less common west of the Rocky Mountains. Under these conditions it must be more common in Colorado than its record would indicate.

194. **Ardea herodias.** GREAT BLUE HERON.

Summer resident, not uncommon; in migration, common. Occurs throughout the lower portions of the State seldom going much above 5,000 feet, but a few find their way into the mountain parks. Around Fort Collins it is a rather common breeder, all the nests being placed on the tops of the tallest cottonwoods on the banks of the Cache La Poudre. In other parts of the State it sometimes selects more lowly nesting sites. Arrives in northern Colorado early in April.

197. **Ardea candidissima.** SNOWY HERON.

Summer visitant; rare; not known to breed. At least seven specimens have been secured in Colorado and several others reported, representing both sides of the range, but all from the lower portions, not above 5,000 feet.

198. **Ardea rufescens.** REDDISH EGRET.

Summer visitant; rare or accidental; not known to breed. In the collection of C. E. Aiken, of Colorado Springs, there is a young bird of this species shot near that city. The bird is not young enough to indicate that it was hatched in the vicinity, but probably wandered north in the fall after having been reared much farther south. This is the only record for Colorado.

202. **Nycticorax nycticorax nævius.** BLACK-CROWNED NIGHT HERON.

Summer resident; not common and local; in migration, not uncommon. Since it occurs through most of the United States, this Heron probably will be found west of the range, but at present all of the records refer to the plains country east of the Rockies and not above 5,500 feet. It breeds throughout its range. There is a heronry of this species a few miles from Fort Collins. Six years ago it consisted of about fifty pairs; now it is reduced to about half that number. The nests are close together occupying less than half an acre on an island in the Cache La Poudre River. The eggs are laid about the first of June, the birds arriving the middle of April.

203. **Nycticorax violaceus.** YELLOW-CROWNED NIGHT HERON.

Summer visitant; rare. A southern species coming casually north to Colorado. Not known to breed. The only recorded specimen is the one in Mrs. Maxwell's collection and that is known to have been taken in Colorado, but where can not now be learned.

204. **Grus americana.** WHOOPING CRANE.

Migratory; rare. A Mississippi Valley species reaching its most western extension in Colorado at the western edge of the plains, where it was first recorded by C. E. Aiken who marks it as "seen occasionally in migration." It has since been noted by Wm. G. Smith at Loveland and there is a very fine mounted specimen in the museum of the State Agricultural College at Fort Collins. Passes through during the first half of April.

205. **Grus canadensis.** LITTLE BROWN CRANE.

Migratory. Not enough material has yet been accumulated to give a satisfactory statement of the distribution of this bird in Colorado. All of the earlier records of "*G. canadensis*" refer to the next species now called *G. mexicana*. It is certain that the Little Brown Crane occurs in Colorado in migration for Capt. P. M. Thorne has taken it at Fort Lyon and there is a mounted specimen at the Agricultural College at Fort Collins.

206. **Grus mexicana.** SANDHILL CRANE.

Summer resident; not uncommon locally; in migration, common; winter resident in the southern part of the State. The Rio Grande Valley in Colorado used to be the winter home of thousands of Cranes and even yet they are abundant enough in the fall to induce many parties to go to the San Luis Valley for the express purpose of hunting Cranes. They breed locally throughout their range from 5,000 to 7,500 feet. F. M. Drew mentions that one of their breeding grounds is in Animas Park at 7,000 feet. (B. N. O. C. VI. 1881, 85.) They are also known to breed in Routt County. In the autumn they move higher up, having even been seen passing over above the highest mountain peaks of the State. In the San Luis Valley the migrating birds appear in large numbers about the middle of September and remain until the first of November; they return in the spring any time between the first and twentieth of March, depending on the season, and leave about the first of May. If the Little Brown Crane occurs there it is not distinguished by the hunters from the Sandhill.

212. **Rallus virginianus.** VIRGINIA RAIL.

Summer resident; not uncommon. Though not often seen on account of its retiring habits, this species undoubtedly occurs in migration over all the plains region of Colorado below 5,500 feet. C. E. Aiken took the nest and eggs June 4, presumably in El Paso County. It breeds near Loveland, according to Prof. Wm. Osburn, and a pair is now (June, 1896,) breeding a few miles from Fort Collins.

214. **Porzana carolina.** SORA.

Summer resident; common in suitable localities. One can scarcely go by a marshy spot in Colorado on a summer evening without hearing the note of this bird. It breeds throughout its range from the plains to 7,000 feet. More common during the breeding season in the northern part of Colorado than in the southern.

219. **Gallinula galeata.** FLORIDA GALLINULE.

Summer visitant; rare; not known to breed. Colorado is rather out of the normal range of the Gallinule, but since it is found to the east, south and west of the State, its occurrence here can hardly be considered as accidental. The only record for Colorado is that of Allen and Brewster, who took one at Colorado Springs, May 9, 1883. (B. N. O. C. VIII. 1883, 151.)

221 **Fulica americana.** AMERICAN COOT.

Summer resident, common; in migration, abundant. Breeds throughout the State in suitable places on the plains and in the mountain parks up to 8,000 feet. Reaches northern Colorado the last of March.

223. **Phalaropus lobatus.** NORTHERN PHALAROPE.

Migratory; not uncommon. Breeds far north. Occurs throughout the State from the plains to well up in the mountains. F. M. Drew notes that "May 22, six were killed by flying against telegraph wires at Howardsville, Colo., at 9,500 feet. Unless the flock turned back and retraced fifty miles of their course, they would have to cross the range at 12,000 feet." (B. N. O. C. VI. 1881, 249.) They are usually found below 8,000 feet. Mr. Aiken has taken them several times near Colorado Springs. They cross the plains of northern Colorado the first half of May.

224. **Steganopus tricolor.** WILSON'S PHALAROPE.

Summer resident; not uncommon; in migration, common. The Wilson's Phalarope is more common than the Northern, but there are no records of its occurrence in the mountainous parts of the State. It is a common breeder around the ponds

of northern Colorado below 6,000 feet, even within a few rods of cultivated ground. Eggs have been taken near Fort Collins on June 8. In southern Colorado it is known only as a migrant. Reaches northern Colorado the last of April.

225. **Recurvirostra americana.** AMERICAN AVOCET.

Summer resident; common. Most common on the plains, but occurs in the mountain parks up to 8,000 feet. Rather rare in western Colorado. Henshaw found them breeding abundantly in the San Luis Valley, with nearly all the eggs hatched by June 21. In northern Colorado on the plains the eggs are mostly laid by the first week in June, the birds having come the middle of April.

226. **Himantopus mexicanus.** BLACK-NECKED STILT.

Summer resident; not uncommon. It is found at the same places and at the same time as the Avocet, but the order of abundance is reversed, the Stilt being more common west of the range though still occurring in eastern Colorado. Breeds at the same time as the Avocet from the plains to 8,000 feet.

228. **Philohela minor.** AMERICAN WOODCOCK.

Summer visitant; rare. Colorado marks the extreme western range of the Woodcock and it is found here only to the base of the foothills. The five known instances are all within 50 miles of Denver. H. G. Smith reports one August 12, 1885, and one in October, 1885, within the city limits of Denver. He also reports that one was seen by Mr. John Bently during the fall of 1887 near Boulder and that one was recently shot near Fort Lupton. (Auk, III. 1886, 284 and Nidologist, III. 1896, 65.) Dr. W. H. Bergtold, of Denver, writes that he saw one in Denver, June, 1895. Since the Woodcock breeds throughout its range and since it has been noted here in June and August, it is fair to presume that it breeds occasionally in Colorado, but no nests have as yet been found in the State.

230. **Gallinago delicata.** WILSON'S SNIPE.

Summer resident, rare; in migration, common; winter resident, rare. Found throughout the State in migration anywhere below 10,000 feet, but more common on the eastern slope than the western. F. M. Drew found it breeding in San Juan County (B. N. O. C. VI. 1881, 85), and W. E. D. Scott found a few pairs breeding in June at Twin Lakes at over 9,000 feet. (B. N. O. C. IV. 1879, 90.) On the plains it is known only in migration and a few in winter. Aiken, Morrison and Bennett report it in winter, the first on the plains, the second at Fort Lewis, and the last in Routt County. It has been known to winter at open marshy springs even 150 miles north of Colorado in central Wyoming.

232. **Macrorhampus scolopaceus.** LONG-BILLED DOWITCHER.

Migratory; not uncommon. Probably occurs throughout the lower regions of the State, though all the records are confined to the plains region east of the mountains. It is not uncommon there in migration, passing through about the middle of April. Breeds far north, but a record of one taken by H. W. Henshaw at Denver, July 24, 1873, would lead one to suspect that it may yet be found breeding in the State.

233. **Micropalama himantopus.** STILT SANDPIPER.

Migratory; rare. Only found on the plains of eastern Colorado where it is occasionally met in spring migration in May and early June and less commonly in the fall. It has been reported by Capt. P. M. Thorne, from Fort Lyon, where he killed a female May 22, 1883, with the largest egg the size of No. 6 shot (Auk, IV. 1887, 264), by Prof. Wm. Osburn, from Loveland, by F. Bond, from Cheyenne, and by H. G. Smith, from near Denver. Breeds north of the United States.

239. **Tringa maculata.** PECTORAL SANDPIPER.

Migratory; common. Occurs throughout the State in migration, both on the plains and even up to 13,000 feet in the mountains (Morrison O. & O. XIII. 1888, 107), though of course less common at the higher altitudes. Breeds in the Arctic regions.

240. **Tringa fuscicollis.** WHITE-RUMPED SANDPIPER.

Migratory; not uncommon. A bird of the plains finding its western limit at the base of the Rockies. It has been reported by Thorne, Breninger and Osburn. Breeds far north.

241. **Tringa bairdii.** BAIRD'S SANDPIPER.

Migratory; abundant. In fall migration this is one of the commonest of the Sandpipers, and is also common in spring. Breeds far north but returns early, entering the State again in the latter part of August. When moving northward it is a bird of the plains and the parks below 7,000 feet, but Trippe, Drew and Morrison agree that after the breeding season is over in August and September, it roams to the tops of the loftiest peaks, 13,000 to 14,000 feet, feeding on grasshoppers. Passes through during April and the first half of May.

242. **Tringa minutilla.** LEAST SANDPIPER.

Migratory; common. Arrives the latter part of April and is mostly gone by the middle of May. Is found principally on the plains and below 7,000 feet in the mountains.

243a. **Tringa alpina pacifica.** RED-BACKED SANDPIPER.

Migratory; rare. There are but three Colorado records for this species, which is found throughout North America. There was an adult in winter plumage in Mrs. Maxwell's collection, and Wm. G. Smith took it at Loveland, April 29 and May 9. Breeds far north.

246. **Ereunetes pusillus.** SEMIPALMATED SANDPIPER.

Migratory; not uncommon. Arrives the last of April and first of May. Mostly on the plains and below 7,000 feet.

247. **Ereunetes occidentalis.** WESTERN SANDPIPER.

Migratory; rare. Should not be an uncommon species in Colorado, but so far has been reported but three times. Prof. Wm. Osburn writes that he shot one at Loveland, July 4, 1889, and another May 12, 1890. W. P. Lowe, of Pueblo, shot two on a lake near there in the fall of 1894. Wm. G. Smith took one at Loveland, May 9, 1890. Breeds far north.

248. **Calidris arenaria.** SANDERLING.

Migratory; rare. Though occurring over most of the world, it is quite rare on the plains region of the United States. Prof. Wm. Osburn reports three captures at Loveland, September 24, 1889, September 30, 1889, and May 12, 1890. H. G. Smith saw one May 16, 1888, that had been taken a few days before at Sloan's Lake, near Denver. There is a mounted specimen at the college at Fort Collins that was shot in the vicinity. Breeds far north.

249. **Limosa fedoa.** MARBLED GODWIT.

Migratory; not common. A bird of the plains not often seen; arrives about the first of May. Has once been taken in the mountains by C. E. Aiken at the San Luis Lakes, October 1, 1874. Drew gives it as breeding on the plains, which it does in Nebraska, but there seems to be no record as yet of its nests being found in Colorado.

254. **Totanus melanoleucus.** GREATER YELLOW-LEGS.

Migratory; common. Found both spring and fall everywhere in favorable localities below 7,000 feet. It is a little strange that neither the Greater nor the Lesser Yellow-Legs is know to breed in Colorado, since they both breed in Nebraska but a few miles from the northeast corner of Colorado. They reach northern Colorado about the first of April.

255. **Totanus flavipes.** YELLOW-LEGS.

Migratory; common Distribution and migration the same as that of the Greater Yellow-Legs but in most places not

quite so numerous. Capt. Thorne shot one at Fort Lyon July 23, which would indicate that it nested not far distant.

256. **Totanus solitarius.** SOLITARY SANDPIPER.

Summer resident, not common; in migration, common. Occurs both on the plains and in the mountains. Arrives in April and most pass on to breed north of the United States, but a few remain to breed from the plains at the eastern base of the mountains up to 10,000 feet.

258a. **Symphemia semipalmata inornata.** WESTERN WILLET.

Summer resident; not uncommon. Rather common in migration on the plains, especially in the fall. In the spring it is most common from the first to the middle of May. Breeds throughout its range in favorable localities, but it is not a common breeder anywhere in Colorado and will not be found breeding at many places apparently well suited to its needs. Usually breeds from the plains to 7,000 feet, but occasionally much higher.

261. **Bartramia longicauda.** BARTRAMIAN SANDPIPER.

Summer resident, common; in migration, abundant. A bird pre-eminently of the plains, where it breeds abundantly; only rarely met west of the mountains. Arrives the latter part of April and extends into the mountains only to 6,000 feet.

263. **Actitis macularia.** SPOTTED SANDPIPER.

Summer resident; abundant. It is strange to think of a Sandpiper nesting on the top of a mountain, but so far up as this species can find a pond or small lake, it will build its nest, even to 12,000 feet. In the fall it ranges above the pines to 14,000 feet. It also breeds on the plains and at all intermediate altitudes. As abundant in Colorado as anywhere. Arrives about the first of May; leaves the higher altitudes in August, and most of them leave the State in September. A few remain until far into the winter, if not through the entire cold season.

264. **Numenius longirostris.** LONG-BILLED CURLEW.

Summer resident; common. Arrives about the last of April and breeds in suitable localities on the plains. Occurs on both sides of the range, but only in the lower portions, usually not above 5,000 feet. A few have been seen as high as 7,500 feet.

265. **Numenius hudsonicus.** HUDSONIAN CURLEW.

Migratory; rare. All the records of this Curlew in Colorado come from the plains region east of the mountains, but as

it occurs over all of North America, it will probably yet be taken on the prairies of western Colorado. Arrives about the first of May and breeds far north.

[266. **Numenius borealis.** ESKIMO CURLEW.

Migratory; rare. There is no reason to doubt that of the enormous flocks of this Curlew that pass over western Kansas, some occasionally enter Colorado; but to date there is no certain record of its capture in the State. It has been previously listed as a Colorado bird, but the record was based on error.]

270. **Squatarola squatarola.** BLACK-BELLIED PLOVER.

Migratory; not common. Passes north through Colorado in May and returns in October. More common in fall than in spring. It is a bird of the plains below 5,000 feet. There are eight recorded instances of its capture at Denver, Loveland and Fort Collins, and Mr. C. E. Aiken has taken it several times near Colorado Springs. Breeds far north.

272. **Charadrius dominicus.** AMERICAN GOLDEN PLOVER.

Migratory; not common. A few pass in the spring and fall over the plains region of Colorado below 5,000 feet. Breeds far north.

273. **Ægialitis vocifera.** KILLDEER.

Summer resident; abundant. One of the earliest migrants, arriving early in March and remaining until the last of September and a few much later. Breeds abundantly on the plains and at the base of the foothills. Is less common in the mountains, but is far from scarce up to the pines at about 10,000 feet. The eggs are laid from the middle of May to the first of June.

274. **Ægialitis semipalmata.** SEMIPALMATED PLOVER.

Migratory; not common. Passes through Colorado on its way from its breeding grounds near the Arctic Circle to its winter habitation which is sometimes far south of the equator. One was shot by Harry Smith at Loveland, May 6, 1890, and the specimen is now in the collection of Prof. Wm. Osburn. This is the only record to date for Colorado.

281. **Ægialitis montana.** MOUNTAIN PLOVER.

Summer resident; common. A bird of the plains rather than the mountains, but also found in the mountain parks and prairies up to 8,000 and rarely to 9,000 feet. Is among the earliest spring arrivals, reaching central Colorado by the last of March to the first week in April. Eggs are laid the latter part of May to the middle of June. On the plains the young are hatched by the last of June; in the mountain parks newly hatched young can be found all through July. Breeds throughout its range. Leaves the state in the fall, the latter part of October. Its number can be judged by the fact that in one day of August at Fort Lyon, Capt. Thorne shot one hundred and twenty-six birds.

283. **Arenaria interpres.** TURNSTONE.

Migratory; rare. A few pass through Colorado on their way to and from their far northern breeding grounds. According to H. G. Smith an adult was shot April 26, 1890, at Sloan's Lake near Denver. (Nidologist, III. 1896, 95.)

289. **Colinus virginianus.** BOB-WHITE.

Resident; somewhat common locally. There is some dispute as to whether or not this should be called a native species in Colorado. It has been introduced at various places from Pueblo north along the foothills to Fort Collins near the Wyoming line. In many of these places it is quite common, being protected by law. There seems good reason to believe that all of the Quail along the foothills are the descendents of introduced birds. On the plains of eastern Colorado, near the Kansas line, the case is different. The birds are there beyond doubt, and though many of the original settlers are still there, no one knows of their having been introduced. They are known to be native and common in western Kansas and enormously abundant in Indian Territory, but a few miles from southeastern Colorado, so that it is fair to presume that some of the Quail of eastern Colorado are native. Eastern Colorado is well adapted to their needs and if it was not for the cayotes that destroy their eggs and young, they would easily become numerous. Nearly all the Quail are confined to the plains and the foothills below 5,500 feet. A few years ago several pairs were turned loose in Estes Park at about 8,000 feet and occasionally are still heard from. They have also been introduced along the Arkansas River below La Junta and are prospering. They are certainly native on Bear Creek in the extreme southeastern corner of Colorado.

293. **Callipepla squamata.** SCALED PARTRIDGE.

Rare or accidental visitant. A southern species coming north regularly only to southern Arizona and New Mexico. The first record for Colorado is the specimen taken by W. P. Lowe the first week in June, 1895, in the eastern foothills of the Wet Mountains. (Auk, XII. 1895, 298.) A. W. Anthony writes that he saw one in the shop of a taxidermist of Denver during the winter of 1892–3. It was freshly killed and said to have been taken on the Platte River east of Denver.

294. **Callipepla californica.** CALIFORNIA PARTRIDGE.

Resident; local. According to F. M. Drew this species has been introduced in the vicinity of Denver. (Auk, II. 1885, 11.)

295. **Callipepla gambeli.** GAMBEL'S PARTRIDGE.

Resident; rare. Known to occur only in southwestern Colorado, where C. F. Morrison shot three of them 40 miles southwest of Fort Lewis. Across the line in southern Utah and in Arizona they are common.

297. **Dendragapus obscurus.** DUSKY GROUSE.

Resident; common in the mountains. Its only migration is a slight vertical one. Breeds from 7,000 feet to the border of timber-line, 4,000 feet higher. At the lower altitude the eggs are laid about the middle of May; at timber-line about June 1. Raises but one brood which is hatched about the middle of June. In August they begin to gather into flocks of ten to fifteen individuals and visit the grain fields or the more open gulches and foothills for berries. In September they wander above timber-line to feed on grasshoppers, reaching 12,500 feet. In winter they come down into the thick woods during the severest weather, but many remain the whole year close to timber-line.

300b. **Bonasa umbellus umbelloides.** GRAY RUFFED GROUSE.

Resident; rare. So rare that the present writer has not yet been able to find a hunter who has seen it or even heard of it. Occurs mostly farther north, only a few coming as far south as Colorado. Is found from 7,000 to 10,000 feet; breeds among the pines just below timber-line and retires to the higher foothills in fall and winter.

304. **Lagopus leucurus.** WHITE-TAILED PTARMIGAN.

Resident; common. One of the most strictly alpine birds of the Rocky Mountain region. Fifty years ago the surveying parties of the Pacific Railroads found them breeding on the Snowy Range, and to-day the tourist who visits the highest peaks does not consider he has completed his sight seeing until he has been shown a family of Ptarmigan, or "Mountain Quail" as they are commonly called. They breed entirely above timber-line from 11,500 to 13,500 feet, wandering to the summits of the peaks a thousand feet higher. Nesting begins soon after the first of June, and the young are hatched the early part of July. In southern Colorado eggs have been found as early as the first part of May. Only in the severest winter weather do they come down into the timber, usually to 10,000 feet, but occasionally to 8,000. At that season the sexes are in separate flocks and subsist largely on willow buds. In the winter they are white, changing to the darker mixed color in March and April; by the breeding season in June they have become so close in color to

the moss and rocks that they are apt to depend on this for safety and allow a very close approach. The returning change to white begins in September and is completed in December.

308b. **Pediocætes phasianellus campestris.** PRAIRIE SHARP-TAILED GROUSE.

Resident; not common. There are few parts of the State where the "Pin-tail" can now be called common. Twenty years ago it was plentiful in the northern half of Colorado on the plains and in the foothills up to 7,000 feet on both sides of the range. Even as late as ten years ago it was not uncommon throughout Larimer County. It can be said now to inhabit the same regions, but in such small numbers that its early extermination is probable. A few are still found across the whole of northern Colorado from Nebraska to Utah and south on the plains to at least Burlington and the "Divide" south of Denver. Formerly a few were found throughout the southern half of Colorado, but there are no late records of its occurrence south of the places named. So far as known the present small and scattered flocks of Sharp-tailed Grouse are strictly resident. When they were more abundant they used to perform a short migration in eastern Larimer County, moving into the foothills in the summer and coming down onto the plains in immense flocks in the fall.

[NOTE. It may be that the Sharp-tailed Grouse of Routt County are variety *columbianus*, but all the Colorado birds examined by the present writer are *campestris*.]

309. **Centrocercus urophasianus.** SAGE GROUSE.

Resident; common. As its name implies, it is an inhabitant of the artemesia or sage-brush plains, and is scarcely found elsewhere. It inhabits these favorable localities throughout the State, but it is much more common in the northern than the southern half of the State. It is resident where found, except possibly at some of the higher points to which it moves during the summer. It winters from the plains to 7,000 feet, and regularly breeds to 8,000 feet. A few range in summer as high as 9,500 feet.

310. **Meleagris gallopavo.** WILD TURKEY.

Resident; rare, and will probably soon be exterminated. There still remains a doubt as to whether the eastern Wild Turkey is the variety that occurs in southeastern Colorado. A few years ago these birds were enormously abundant along the Arkansas River in Kansas and Indian Territory, hence it is fair to presume that any found along that river in Colorado would be the same variety especially if found on the plains east of the mountains. Those taken by C. E. Aiken in this locality have

been referred by Ridgway to this form (Bull. Essex Institute V. 1873, 174) with the remark that this is the first Colorado record. This latter statement however is an error, for Lieut. Pike in his memorable journey through Colorado in 1806, found Turkeys so abundant from about where Canon City now stands to the present city of Salida, that they formed a large part of the food of his soldiers. From other sources we know that they extended north along the foothills to within a few miles of the northern boundary of the state. One was taken on the Buckhorn in Larimer County as late as 1861. Turkeys still exist in Bent, Prowers, Baca and Las Animas Counties in southeastern Colorado. A flock of thirty was seen in 1883 on the Purgatoire River east of Trinidad and near the Spanish Peaks as late as 1890. During the winter of 1896-1897 they were seen in Bent County.

310a. **Meleagris gallopavo mexicana.** MEXICAN TURKEY.

Resident; rare, locally. There are a few Turkeys yet to be found in the wilder parts of southwestern Colorado and they are known to belong to the Mexican variety. Chas. F. Morrison found them abundant ten years ago on the Rio los Pinos which runs through the Ute reservation in La Plata County. At an earlier date they were not uncommon along the southern boundary of Colorado from the front range westward. They ascend the mountains only to 7,000 feet.

312. **Columba fasciata.** BAND-TAILED PIGEON.

Summer resident; local. Generally considered as a rare bird in Colorado, but on bringing together all of its records in the State, it is found to have been noted as follows: "Most abundant in southwestern part in scrub oak, feeding on acorns." (Morrison.) "Breeds at Durango up to 7,000 feet." (Osburn.) West base of Spanish Peaks in September, and on September 25 on the Rio Grande at Del Norte. Had been there through the summer. (Henshaw.) "Abundant in the Wet Mountains west of Pueblo from 7,800 to 10,000 feet." (Lowe.) This includes what may be considered its regular range, i. e., from Cañon City west and south. Northeastward it has wandered nearly two hundred miles farther as these records will show. In the fall of 1887 John Bentley saw many of them at Dome Rock in Platte Cañon. The following summer he captured several, some of which were young birds evidently reared in the vicinity. (H. G. Smith.) Seen by my father near Morrison. (Anthony.) In 1820 it was first taken, described and named by Maj. Long's Expedition on the South Platte at the "foot of the mountains" on a small tributary running north and south. This would make it not far from Denver. The most northern record is that of V. L. Kellogg who saw a small flock in Estes

Park during the summer of 1889. (Trans. Kans. Acad. Science, XII. 1889-90, 86.) Breeds from 5,000 to 7,000 feet and occasionally higher.

316. **Zenaidura macroura.** MOURNING DOVE.

Summer resident; very abundant. Arrives the last of March and the early part of April, begins laying early in May and fresh eggs have been found as late as August 12. Breeds everywhere below the pine region up to 10,000 feet, but rather rare above 8,000 feet. In the fall wanders upward to 12,000 feet. Remains late in the fall even to the middle of December in Larimer County.

319. **Melopelia leucoptera.** WHITE-WINGED DOVE.

Accidental. The only claim of this southern species to a place in the list of Colorado birds, rests on the following statement of Dr. Coues: "Mr. E. L. Berthoud informs me of its occurrence near timber-line (11,500 feet), on the head of Cub Creek, Jefferson County. He saw a dozen or more July, 1869." (B. N. O. C. II. 1877, 83). If this is not a case of mistaken identity, it is a strange case of wandering.

325. **Cathartes aura.** TURKEY VULTURE.

Summer resident; common. Occurs throughout the State and breeds from the plains to 10,000 feet. C. F. Morrison found one nest at 12,000 feet on the La Plata Mountains. Is most common on the plains along the base of the mountains. Arrives early in April and nests in the latter part of April and in May.

327. **Elanoides forficatus.** SWALLOW-TAILED KITE.

Summer visitant; rare or accidental. The only record for Colorado is the one seen by Mr. C. E. Aiken, near Leadville, in August, 1871. This is a bird of the plains, not coming regularly west of middle Kansas. It would not be surprising to find it occasionally in southeastern Colorado, but its occurrence west of the range, and at 11,000 feet, is purely accidental.

329. **Ictinia mississippiensis.** MISSISSIPPI KITE.

Accidental. G. F. Breninger writes me that there is a mounted specimen at Denver that was taken at Trinidad. It is rare in eastern Kansas and common southward.

331. **Circus hudsonius.** MARSH HAWK.

Resident; common. Is most common in migration, but is still common as a breeder and a few remain through the winter. On the plains it is one of the most common Hawks. In the mountains it breeds up to 10,000 feet, and in the fall has been seen as high as 14,000 feet. Spring migration begins early in March. It winters on the plains to the northern boundary of Colorado.

332. **Accipiter velox.** SHARP-SHINNED HAWK.

Resident; common. In migration is common throughout the State, and breeds throughout its range, but much more commonly in the mountains than on the plains. Breeds up to 10,000 feet. C. F. Morrison took a set of eggs at Fort Lewis, June 22, 1886.

333. **Accipiter cooperi.** COOPER'S HAWK.

Resident; common. Breeds both on the plains and in the mountains to about 9,000 feet. Along the main range of the mountains it is not so common as the Sharp-shinned Hawk. Dennis Gale found eggs at Gold Hill June 25 and young July 2.

334. **Accipiter atricapillus.** AMERICAN GOSHAWK.

Resident; not uncommon. Is rather more common in winter than in summer. In winter it occurs throughout the State below 9,500 feet; in summer the few that remain are restricted to the mountains, breeding from 9,000 to 10,000 feet.

334a. **Accipiter atricapillus striatulus.** WESTERN GOSHAWK.

Winter visitant; rare, if not accidental. Most of the numerous records of the occurrence of the Western Goshawk in Colorado really refer to the eastern form, which is the common Goshawk of this State. The only certain record of the western form is that of Prof. Wm. Osburn, who says: "A male of this species was captured at Arkins, February 26, 1889, and a female at the same place, March 5. The male was much darker than the female with finer markings on the under parts, corresponding to the description of variety *striatulus*." (Science, XXII. 1893, 212.) This is the Pacific Coast Goshawk coming east regularly to Idaho.

337a. **Buteo borealis kriderii.** KRIDER'S HAWK.

Resident; not uncommon. There is a slight question yet as to the distribution of the three varieties of Red-tailed Hawks that occur in Colorado. It has been taken for granted that all the records of typical *borealis* for Colorado should be referred to some of the other forms, though it is not unlikely that it may rarely visit the extreme eastern portion of the State. There can be no doubt that Krider's Hawk occurs on the plains in Colorado during migration, and the present writer feels sure that the record of its nesting there is also correct. F. M. Dille reports that it nests on plains and large cliffs; one nest in Weld County was taken May 24. Of the occurrence and breeding of Krider's Hawk in the mountains there is more question. It probably does occasionally visit the eastern foothills of the main range, but there is as yet no unquestionable record of its nesting above 6,000 feet.

337b. **Buteo borealis calurus.** WESTERN RED-TAIL.

Resident; abundant. Is the common Rocky Mountain form overlapping the range of Krider's Hawk and breeding from the plains to 12,000 feet in the mountains. Is one of the most common hawks of the State through the summer and not a few spend the winter in Colorado.

337d. **Buteo borealis harlani.** HARLAN'S HAWK.

Winter visitant; rare. One specimen taken by C. E. Aiken at Colorado Springs. (Ridgway, Auk, II. 1885, 165.) One was probably taken by Capt. P. M. Thorne at Fort Lyon.

339b. **Buteo lineatus elegans.** RED-BELLIED HAWK.

Migratory; rare. Included in the list of Colorado birds on the strength of the following note from Geo. F. Breninger: "I saw one at Table Rock, a full plumaged bird with the breast to me; saw one at Fort Collins. I have handled them here in California and there is not the least doubt in the matter."

342. **Buteo swainsoni.** SWAINSON'S HAWK.

Resident; common. More common on the plains than in the mountains. Breeds throughout the State everywhere below 11,000 feet. Begins building its nest the last of April, eggs are laid the middle of May and the young appear early in June. Sometimes very abundant locally. A. S. Bennet of Lay, Colo., says he saw a flock of five hundred July 10, 1889.

347a. **Archibuteo lagopus sancti-johannis.** AMERICAN ROUGH-LEGGED HAWK.

Winter resident; not uncommon. Arrives from the north in November and remains until March. Is usually found in the lower parts of the mountains and on the plains.

348. **Archibuteo ferrugineous.** FERRUGINOUS ROUGH-LEG.

Resident; rather common. Breeds both in mountains and on plains, but in the winter is mostly confined to the plains and the lower streams below 6,000 feet. Breeds at least as far south as Pueblo and thence to British America. Eggs have been taken in Colorado as early as April 13, and well-grown young by May 24; but three to four weeks later than these dates is the more common time.

349. **Aquila chrysaëtos.** GOLDEN EAGLE.

Resident; common in favorable localities. In few, if any, parts of the United States is the Golden Eagle more common than in the more mountainous portions of Colorado. They breed from the foothills to at least 12,500 feet. In the winter they wander occasionally over the plains, but are also found in

the mountains to 11,000 feet. The nest is repaired for the season about the first of March, and the young are hatched about three months later.

352. **Haliæetus leucocephalus.** BALD EAGLE.

Resident; fairly common. Mostly in the mountains in the summer time and on the plains during the winter. Breeds in the mountains to 9,000 feet and occasionally higher; breeds less commonly on the plains. Capt. Thorne found a nest with two young, June 12, near Fort Lyon on the Arkansas River.

355. **Falco mexicanus.** PRAIRIE FALCON.

Resident; not uncommon. Breeds from the plains to 10,000 feet. In some of the more open portions of western Colorado it is quite numerous. Nearly all leave the State in the winter, returning in March and April. The eggs are laid in May.

356. **Falco peregrinus anatum.** DUCK HAWK.

Resident; not uncommon, locally. Has been reported from many places in the State. W. P. Lowe found the nest and young in St. Charles Cañon, near Pueblo, during the summer of 1895. Dennis Gale took a set of eggs on the Poudre River, April 30, 1889. Others report it as breeding up to 10,000 feet in the mountains.

357. **Falco columbarius.** PIGEON HAWK.

Summer resident; rather uncommon; in migration fairly common; a few remain through the winter in the lower portions. The eggs have been taken in various parts of the State, from the plains to about 9,000 feet, but more commonly from 8,000 to 9,000. Eggs are laid about the first of June.

358. **Falco richardsonii.** RICHARDSON'S MERLIN.

Summer resident; rare; in migration not uncommon. There are several references to its breeding in the State, as it undoubtedly does, but this seems to have been inferred from its being seen here in summer rather than from its nest and eggs having been actually taken. Drew states that it breeds from the plains upward. It has been taken in summer as high as 11,000 feet. In migration occurs throughout the State.

360. **Falco sparverius.** AMERICAN SPARROW HAWK.

Resident; abundant. The most common hawk from the plains to 11,000 feet. In mild winters, like that of 1895-6, quite a number remain throughout the lower portions of the state, but the bulk winter farther south, returning early in March. Eggs are laid the latter part of April and fully fledged

young are around by the middle of July. Breeds from the plains to 11,500 feet and in the fall ascends to the highest peaks, feeding on mice and grasshoppers.

364. **Pandion haliaëtus carolinensis.** AMERICAN OSPREY.

Summer resident; not uncommon, locally. W. E. D. Scott found a pair breeding at Twin Lakes at about 9,000 feet. (B. N. O. C. IV. 1879, 90.) It is said to begin laying the last of April, but Mr. Scott found eggs as late as the middle of June. Has been taken in the fall as high as 10,500 feet.

365. **Strix pratincola.** AMERICAN BARN OWL.

Resident; very rare. The only record for Colorado is the one mentioned by H. G. Smith as caught in the Town Hall of South Denver. (Nidologist, III. 1896-7, 76.) A southern species rarely coming so far north as Colorado. The above record of "resident" is made not so much from the instance cited, as from its general distribution and the fact that it has been found breeding in Nebraska near the Colorado line.

366. **Asio wilsonianus.** AMERICAN LONG-EARED OWL.

Resident; common. Winters from the plains to 10,000 feet and breeds from the plains to 11,000. Eggs are laid early in April.

367. **Asio accipitrinus.** SHORT-EARED OWL.

Resident; not common. Much less common than the Long-eared and nearly confined to the plains. The highest record is a little below 8,000 feet. Breeds throughout its range in Colorado, but rather more common in summer in northern than southern Colorado. Begins laying in April.

369. **Syrnium occidentale.** SPOTTED OWL.

Resident. There is no reason to doubt the occurrence of this species in the State, but its record for Colorado is badly mixed. All Colorado records are known to be incorrect except the statement by H. G. Smith that C. E. Aiken has taken several Owls of this species. (Auk. III. 1886, 284.) Though the correctness of this statement has been challenged, yet Mr. Aiken has lately informed the present writer that there can be no question of the identification.

372. **Nyctala acadica.** SAW-WHET OWL.

Resident; not uncommon. Occurs throughout the State below 8,000 feet, but all the records of breeding come from the mountains between 7,000 and 8,000 feet. Eggs are laid the latter part of May. H. G. Hoskins writes that he found one at Beloit, near the Kansas line, April 9, 1894. H. G. Smith records three cases in the vicinity of Denver.

373. **Magascops asio.** SCREECH OWL.

Resident; rare. The western range of *asio* and the eastern extension of *maxwelliæ* and *aikeni* have not been satisfactorily determined. *Asio* is the common form of western Kansas and western Nebraska, and *maxwelliæ* is the common form of the foothills and extending at least thirty miles out on the plains. Between these known points lie nearly two hundred miles of plains, which form an unknown land so far as Screech Owls are concerned. That *asio* does sometimes come into Colorado is proved by the capture of one in the mottled phase near Greeley, as reported to the present writer, by Pres. Z. X. Snyder. According to Capt. P. M. Thorne, there is a Screech Owl inhabits the timber along the Arkansas River at Fort Lyon. No specimens were obtained. It must be either *asio* or *aikeni*, and of the two it is more likely to be *asio*.

373e. **Magascops asio maxwelliæ.** ROCKY MOUNTAIN SCREECH OWL.

Resident; common. According to present ideas this form occurs in the mountains of Colorado from the central part of the State northward, and from the foothills to about 6,000 feet. It has been reported breeding from Denver, Boulder and Loveland. Eggs are usually laid about the middle of April, but have been found as early as the first of April and as late as the last of May. V. L. Kellogg records it as a rare visitant at Lamb's ranch in Estes Park. (Trans. Kans. Acad. Science, XII. 1889-90, 86.) This ranch has an altitude of nearly 9,000 feet.

373g. **Megascops asio aikeni.** AIKEN'S SCREECH OWL.

Resident. Type from El Paso County. E. M. Hasbrouck, in summarizing the records of this species, says that it probably does not occur north of Douglas County anywhere in Colorado. It is a bird of the more open country along the foothills of the Rocky Mountains, south to central New Mexico and northeastern Arizona. Apparently not found below 5,000 feet nor above 9,000. Hasbrouck refers to this variety, Morrison's "Mccalli," from La Plata County. (Auk, X. 1893, p. 250.) W. P. Lowe, of Pueblo, writes that a Screech Owl, presumably this variety, is rather common in the foothills of the Wet Mountains and that he once found it breeding at 7,800 feet.

374. **Megascops flammeola.** FLAMMULATED SCREECH OWL.

Resident; rare. The rarest owl in Colorado, if not in the United States. All the known specimens from Colorado have been taken along the main front range of the Rocky Mountains, from Estes Park to the San Luis Valley. The first record for Colorado is the specimen in the Maxwell Collection, taken at Boulder, in March of some year previous to 1876.

(Ridgway, Field and Forest, II. 1876-77, 195 and 208). The second, by C. E. Aiken, at Poncha Pass, Fremont County, June 15, 1875, and the nest with one egg, being the first nest of this species known to science. (Deane, B. N. O. C. IV. 1879, 188.) The third was shot by Dr. Walbridge, at Mosca Pass in the San Luis Valley, the third week in August, 1879. (Ingersoll, B. N. O. C. V. 1880, 121.) The fourth was found dead in 1883 in the same place where Dr. Walbridge took his specimen. The fifth, by C. E. Aiken, in nestling plumage, about the middle of September, 1883, near Colorado City, at an altitude of 7,500 to 8,000 feet. (Fourth and fifth specimens, Brewster B. N. O. C. VIII. 1883, 123.) The sixth, seventh and eighth, by W. G. Smith; in Estes Park, one June 2, 1890, a female and nest with three fresh eggs, at 10,000 feet; one June 4 at the same altitude, a female, nest and two fresh eggs; one June 20, a female, nest and four partly incubated eggs at 8,000 feet. (O. and O. XVI. 1891, 27.) The ninth, by Evan Lewis, near Idaho Springs, June 7, 1890, a nest with three eggs at 8,700 feet. (Bendire, Life Histories N. Am. Birds, 1892, p. 375.) The tenth was taken July 17, 1884, near Evergreen P. O., Jefferson County. (H. G. Smith, Auk, X. 1893, 364.) In addition to these only six other specimens are known from the rest of the United States, and there are no records of its breeding anywhere but in Colorado. There is a specimen in the National Museum at Washington that bears the date June 10, 1890 and was taken in Estes Park by W. G. Smith. It is presumably one of the three mentioned above, but it cannot now be learned which one it is. Mr. Dennis Gale writes that he took one twelve miles from Gold Hill in the direction of Estes Park. This makes the eleventh specimen for Colorado. Of these eleven, seven have been taken in Boulder County or vicinity.

375a. **Bubo virginianus subarcticus.** WESTERN HORNED OWL.

Resident; common. Not enough material has accumulated to define the range of the different forms of the Horned Owl in Colorado. The following statements are given with the knowledge that they are far from complete and quite liable to error. But they seem to be the best explanation that can be given of the known facts. The second edition of the A. O. U. Check List gives *subarcticus* as the only form breeding in Colorado, confining *arcticus* during the summer to Arctic America, with a southern migration in winter to Montana and Wyoming. The earlier writers went to the opposite extreme and referred all Colorado birds to *arcticus*. The present writer is inclined to accept the theory that *subarcticus* is the form of the lower portions of the State, breeding commonly along the timbered river bottoms. How far this form extends into the mountains is not

now known. There certainly is a Horned Owl that breeds in the mountains even up to 11,000 feet, and either this or some closely related form is found in winter nearly to the limit of trees. It is probable that these winter birds belong to both *subarcticus* and *arcticus*, and that the summer birds are principally, if not entirely, *subarcticus*, though largely partaking of the character of both forms.

375b. **Bubo virginianus arcticus.** ARCTIC HORNED OWL.

Winter visitant; not uncommon. That this variety occurs in Colorado at any time in the year has been often denied. All doubts on the subject were lately settled by a specimen that Mr. C. E. Aiken lately sent to the present writer and which has been identified by Mr. Ridgway as undoubtedly *arcticus*. Mr. Aiken writes about these birds, that there was "an owl I had mounted twelve or fourteen years ago which I called *arcticus*. That specimen was a little more white and probably nearer the type than the present one. Both birds were brought to me by boys who had killed them near town [Colorado Springs,] but whether in the mountains or along the creek below town I cannot say. We have a flight of the lighter marked owls late in the fall, quite regularly, but I think the two under consideration are the only ones I have seen quite so light. I think both these birds were killed in November." Writing some years ago about *arcticus*, Mr. C. F. Morrison says: "This is the variety to which I refer the mountain specimens, they showing as much difference from the plains specimens of *subarcticus* as my Montana birds do, and in some cases even lighter. Do not know just where to draw the line, but I think true *arcticus* will be found as far south as the southern border of the State in the main chain of the Rockies." Prof. Wm. Osburn says that one he has referred to this variety was shot in the mountains near Loveland November 29, 1890. It was nearly white.

[375c. **Bubo virginianus saturatus.** DUSKY HORNED OWL.

Resident; not common. In time the above record of this variety will probably be shown to be correct, but at the present time it is hardly a scientific statement It has been but once formally stated as occurring in Colorado (Fisher, Hawks and Owls of the U. S., 74), and that is based on a misquotation, the birds having been found in Arizona instead of Colorado. Moreover all writers on Colorado birds agree that the Horned Owls of the mountains are a light colored race showing a tendency toward *arcticus* instead of *saturatus*. Nevertheless it is almost certain since the variety has been found common a few miles from the southwest corner of Colorado that it does really inhabit the higher mountains in the coniferous forests]

376. **Nyctea nyctea.** SNOWY OWL.

Winter visitant; rare. More than a score of cases are known of its occurring in winter on the plains and the lower foothills of eastern Colorado to about the central part of the

State. It was unusually common around Denver during the winter of 1886–7. One was captured alive near Fort Collins in the early winter of 1896–7.

378. **Speotyto cunicularia hypogæa.** BURROWING OWL.

Resident; abundant locally. Breeds from the plains to 8,000 feet regularly, less commonly to 9,000 feet and only occasionally seen at 10,000 feet. It is found clear across the State to Utah. Begins laying the latter half of April and eggs have been found in northern Colorado as late as the first of July. The Burrowing Owl is a partial migrant in northern Colorado and in the higher altitudes, but there is need of more precise knowledge concerning its movements.

379. **Glaucidium gnoma.** PYGMY OWL.

Resident; rare. Occurs throughout the whole State west of the foothills, but no records as yet for the plains, except the single specimen taken in winter at Loveland by W. G. Smith, and that was but ten miles from the foothills. Mr. Smith also found the nest, with just hatched young, May 31, 1890, in Estes Park, at 10,000 feet, while in the extreme southwestern part of the State, at 1,000 feet lower, C. F. Morrison found four nests with eggs the first half of June, 1886. W. P. Lowe reports it as common in the Wet Mountains from 7,800 to 10,000, while E. B. Darnall writes that it occurs in Routt County in northwestern Colorado, below 6,000 feet. One was taken at Denver by H. G. Smith, February 18, 1888, and one during the winter of 1888–9 near Durango.

382. **Conurus carolinensis.** CAROLINA PAROQUET.

Formerly resident. The only record for Colorado is that of E. L. Berthoud, who wrote to Dr. Coues: "I saw the Carolina Parrot at this place (Goldèn) and at Denver on the South Platte in 1860-61, and on the Little Thompson River, Colorado, in 1862. I have also seen it near old Fort Lyon, on the Arkansas River. (Coues, B. N. O. C. 1877, 50.)

385. **Geococcyx californianus.** ROAD-RUNNER.

Resident; not common. Has been recorded along the southern border of Colorado from the extreme southeastern to the extreme southwestern corner. Its first Colorado record was by C. E. Aiken from El Paso County, and that still remains as the most northern record. There was a specimen in Mrs. Maxwell's collection at Boulder, but it probably was taken in southern Colorado. Breeds throughout its range. Rarely found above 5,000 feet, but W. P. Lowe writes that he once saw one at 8,000 feet in the Wet Mountains. According to Henshaw the young hatch the last of July.

387. **Coccyzus americanus.** YELLOW-BILLED CUCKOO.

Summer visitant; rare. The only claim this species has for admission to the list of Colorado birds is the statement by Major C. Bendire that it extends "casually to eastern Colorado." (Life Hist. N. Am. Birds Part II, 19.) It is probably now too late to ascertain the foundation for this statement. It must be rare in Colorado for all the specimens taken at Fort Lyon, only a few miles from the eastern boundary of the State, are *occidentalis.*

387a. **Coccyzus americanus occidentalis.** CALIFORNIA CUCKOO.

Summer resident; not uncommon locally. Occurs throughout the State, below 8,000, but most common on the edge of the plains. Specimens taken almost to the Kansas line are found to be this variety. Breeds throughout its range in Colorado.

388. **Coccyzus erythrophthalmus.** BLACK-BILLED CUCKOO.

Migratory; rare. There is a mounted specimen in the museum of the Agricultural College at Fort Collins, taken near there on June 11, by G. F. Breninger. Prof. Wm. Osburn writes that he took one at Loveland, at which place one was also taken by W. G. Smith. These are all the present records for Colorado, though it probably some time will be found here breeding.

390. **Ceryle alcyon.** BELTED KINGFISHER.

Resident; common. Breeds throughout the State, from the plains to 10,000 feet, although it is more common on the lower streams. A few remain even during severe winters along the foothills almost to the northern boundary of the State.

393d. **Dryobates villosus hyloscopus.** CABANIS'S WOODPECKER.

Resident; common. Breeds from the plains to 11,000 feet and winters at almost as great an elevation. But the larger number breed among the pines in summer time and return to lower altitudes for the winter. Eggs are laid early in May.

394. **Dryobates pubescens.** DOWNY WOODPECKER.

Visitant; rare, if not accidental. Included among Colorado birds on the strength of the note of Maj. Bendire that it extends "irregularly to Colorado." (Life Hist. N. Am. Birds, part II. 55.) It is probable that this statement is based on the geographical range for this species as given in Ridgway's Man-

ual, "Northern and Eastern North America and sporadically Western North America (Colorado, California, etc.)." The birds there referred to by Mr. Ridgway as being found in the west are now considered by him as belonging to *homorus*. As the authority for Maj. Bendire's remarks cannot be now learned they are entered here to call attention to the record.

394b. **Dryobates pubescens homorus.** BATCHELDER'S WOODPECKER.

Resident; common. Hardly as common in Colorado as its eastern representative is in the Mississippi Valley and much less common than Cabanis's Woodpecker. To this form are now referred all Colorado birds. It ranges in winter from the plains to 10,000 feet and breeds from the plains to 11,500, but is more common at the higher altitude in summer and at the lower in fall and winter.

396. **Dryobates scalaris bairdi.** TEXAN WOODPECKER.

Resident; rare and local. It is rather strange that this bird should have been overlooked by previous collectors, as W. P. Lowe writes that it occurs regularly in Pueblo and Huerfano Counties. More commonly seen in spring and fall and occasionally an old bird in winter. Mr. Lowe has taken several of the birds and the skins have been positively identified, so there can be no doubt of its occurrence as he states. This is the first and only Colorado record for the bird and carries its known range over three hundred miles to the eastward.

401b. **Picoides americanus dorsalis.** ALPINE THREE-TOED WOODPECKER.

Resident; not common. Throughout the mountains from about 8,000 to 12,000 feet. Occasionally a few feet lower, but remains even in winter in the pine belt chiefly at about 10,000 feet. It is not common anywhere but is scattered quite generally through the mountains. D. D. Stone found a nest with five young birds near Hancock, July 10, 1883, at about 10,000 feet. (O. & O. IX. 1894, 9 and 10.)

402. **Spyrapicus varius.** YELLOW-BELLIED SAPSUCKER.

Migratory; rare. The eastern variety scarcely coming west to the Rocky Mountains. It was taken by C. E. Aiken, presumably in El Paso County, and there is a single specimen in the Maxwell Collection.

402a. **Sphyrapicus varius nuchalis.** RED-NAPED SAPSUCKER.

Summer resident; common. Breeds from the plains to 12,000 feet, but the great bulk of nests are made between 8,000 and 9,000 feet. Arrives in April but eggs are not found until the first half of June.

404. **Sphyrapicus thyroideus.** WILLIAMSON'S SAPSUCKER.

Summer resident; common. Breeds from 5,000 feet to the upper limit of the pines. In southern Colorado is most common from 9,000 to 10,000 feet; in northern Colorado from 6,000 to 9,000 feet includes the great bulk of the birds. Arrives the first week in April and eggs are laid the last half of May.

405. **Ceophlœus pileatus.** PILEATED WOODPECKER.

Resident; very rare. The A. O. U. Check List gives its geographical distribution as "Formerly the heavily wooded region of North America south of about Lat. 63°, except in the southern Rocky Mountains; now rare or extirpated in the more thickly settled parts of the Eastern States." That it is rare in the Rocky Mountains of Colorado is certain, and it is not sure that it occurs there at all. F. M. Drew says that in southwestern Colorado "I have been told of a great big woodpecker and from the description think it is this bird." (B. N. O. C. VI. 1881, 85 and 138.) H. G. Hoskins writes that while passing Tuttle Ranch he saw a large crested Woodpecker that he took to be this species. Tuttle Ranch is only a few miles from the Kansas line and as this species is known to occur only a little farther east, it is probable that Mr. Hoskins' identification is correct.

406. **Melanerpes erythrocephalus.** RED-HEADED WOODPECKER.

Summer resident; common. Breeds on the plains and up to 10,000 feet. Rather more common on the plains than in the mountains. One of the latest migrants, not reaching northern Colorado until the last week in May. Eggs are not laid until late in June.

408. **Melanerpes torquatus.** LEWIS'S WOODPECKER.

Resident; common. Winters from the plains to the lower foothills and breeds from the edge of the plains to about 8,000 feet. Regularly passes but a few miles out on the plains, but has been taken in Finney County in southwestern Kansas, April 23, 1893, and Capt. P. M. Thorne saw two at Fort Lyons on the Arkansas River. A very characteristic bird of the lower foothills and has been seen as high as 10,000 feet in southern Colorado, though probably does not breed above 9,000 feet. Performs a slight southward migration, but most of its movements are merely to retire a few feet lower during the winter season. Breeds late in June.

409. **Melanerpes carolinus.** RED-BELLIED WOODPECKER.

Summer visitant; rare, if not accidental. A southern and eastern species not regularly occurring farther west than central

Kansas. One was taken by C. E. Aiken, and there are both a male and a female in the Maxwell Collection. In 1895, Pres. Z. X. Snyder saw one near Greeley.

412. **Colaptes auratus.** FLICKER.

Migratory; rare. The eastern form only extends west across the plains to the foothills and there is no record of its breeding, though a few may winter. Taken by Capt. Thorne at Fort Lyons, December 10, 1883, and by Prof. Osburn at Loveland during the fall migration, September 24, 1889. One was taken by the Pacific Railroad surveying parties on the South Platte.

413. **Colaptes cafer.** RED-SHAFTED FLICKER.

Summer resident; abundant. Breeds from the plains to 12,000 feet and is almost as common at 11,000 feet as on the plains. An early migrant reaching northern Colorado by the first week in April and in mild winters, like that of 1895-6, remains all winter throughout the plains region. Even in the severest winter a few linger in the State. Eggs are laid from the last of May on the plains to the middle of June in the mountains. Most of the birds leave the mountains early in November, and the State by the first of December.

418. **Phalænoptilus nuttalli.** POOR-WILL.

Summer resident; common. Breeds on the plains and in the mountains to at least 8,000 feet, while it has been noted as high as 10,000 feet in the mountains of southern Colorado. Arrives about the middle of May and the eggs are laid the latter part of June. Remains in the fall until October.

418a. **Phalænoptilus nuttalli nitidus.** FROSTED POOR-WILL.

Summer resident; rare. In his original description of this variety, Mr. Brewster says that Colorado birds are true *nuttalli*, and this is of course true for the great bulk of the birds all over the State. But in southeastern Colorado *nuttalli* becomes mixed with *nitidus*. Of three specimens taken by Capt. Thorne at Fort Lyon, Mr. Brewster marks two as typical *nuttalli* and the other as not typical and nearest *nitidus*. The latter specimen is now in Mr. Brewster's collection. As *nitidus* comes north regularly to western Kansas, there is no reason why it should not occur in southeastern Colorado.

420a. **Chordeiles virginianus henryi.** WESTERN NIGHT-HAWK.

Summer resident; abundant. Breeds on the plains and up to about 11,000 feet; in the fall wanders to 12,000 feet. Is rather more common on the plains and lower foothills than

higher up, but is still common to 10,000 feet. Reaches northern Colorado the last of May and nests by the middle of June. Eastern Colorado is within the geographical range of *C. v. sennetti*, but it has not yet been reported from the State.

422. **Cypseloides niger borealis.** BLACK SWIFT.

Summer resident; abundant, locally. Occurs regularly in southwestern Colorado, where it was found by F. M. Drew, who says that they come late in June and leave late in September; breed from 10,000 to 12,000 feet, and range far above 13,000 feet. Are very common and always hunt in large flocks. (B. N. O. C. VII. 1882, 182 and B. N. O. C. VI. 1881, 85 and 138.) Has been taken by Dr. A. K. Fisher as far east as Trinidad. (Bendire, Hist. N. Am. Birds, Part II. 175.)

455. **Aëronautes melanoleucus.** WHITE-THROATED SWIFT.

Summer resident; not uncommon, locally. Breeds only in inaccessible rocks from the lower foothills at about 6,000 feet to at least 12,000 feet if not higher. Arrives the last of March to the middle of April. More common in the southern half of the State, but breeds at 7,000 feet on Horsetooth Mountain a few miles from Fort Collins and passes north into Wyoming.

429. **Trochilus alexandri.** BLACK-CHINNED HUMMINGBIRD.

Summer resident; not uncommon, locally. Occurs only in the extreme western and southwestern part of Colorado, and there only in the lower portions below 6,000 feet.

432. **Selasphorus platycercus.** BROAD-TAILED HUMMINGBIRD.

Summer resident; common. The most common Hummer in Colorado. Arrives early in May and breeds from the foothills to 11,000 feet. Ranges 2,000 feet above timber-line in summer time. Breeds most commonly from 7,000 to 9,000 feet. First set of eggs is laid about the middle of June and, at least in southern Colorado, two broods are reared. The young from the later brood are scarcely out of the nest by the middle of August and a few weeks later the birds start southward. Records are lacking for the plains region east of the foothills, though common clear to the edge of the plains.

433. **Selasphorus rufus.** RUFOUS HUMMINGBIRD.

Summer resident; not uncommon locally. A western species coming into southwestern Colorado, where it breeds from 7,000 to 10,000 feet and ranges in summer several thousand feet higher. Tolerably common in western Colorado and much less common along the eastern slope of the mountains.

The most northeastern record is that of Mr. W. G. Smith who took it in Larimer County. One was taken by Mr. Dennis Gale near Boulder and a specimen was taken by Henshaw at Fort Garland, August 12, during the fall migration. There is a specimen in the Maxwell Collection, but no data as to where it was captured.

443. **Milvulus forficatus.** SCISSOR-TAILED FLYCATCHER.

Summer visitant; rare, if not accidental. The only record for Colorado of this southern species is that of G. F. Breninger. He writes that he saw one at Table Rock, on the Divide, south of Denver. He says, "I saw the bird close to and there is no doubt in the matter."

444. **Tyrannus tyrannus.** KINGBIRD.

Summer resident; common. Occurs regularly only on the plains and a little way up the eastern foothills to 6,000 feet. Breeds throughout its range. Has been taken as a rare visitant in Routt County, in northwestern Colorado. Arrives about the first week in May.

447. **Tyrannus verticalis.** ARKANSAS KINGBIRD.

Summer resident; common. Gets its English name from having been originally described by Say, from specimens taken on the Arkansas River [notwithstanding the statement in Baird, Brewer and Ridgway's Birds of North America that they were taken on the Platte]. Rather more common in eastern than western Colorado, especially on the plains at the base of the foothills. Scarcely found in the mountains, rising regularly only to 7,000 feet, breeding from there down to the plains. Arrives the first week in May and nests about the middle of June. After the young are able to fly, about the first of August, a few wander into the mountains to 8,500 feet.

448. **Tyrannus vociferans.** CASSIN'S KINGBIRD.

Summer resident; common. Occurs throughout Colorado, breeding from the plains to 7,000 feet and is fairly common even to the northern boundary of the State, though more common in the southern two-thirds. Arrives the second week in May. There are no records on the plains more than about fifty miles out from the foothills.

454. **Myiarchus cinerascens.** ASH-THROATED FLYCATCHER.

Summer resident; rare. A western species, coming east to the western edge of the plains. Breeds from the plains to 7,000 feet. Arrives the last of May and departs south late in October. The most northeastern record is one taken at Golden by Prof. Osburn.

455a. **Myiarchus lawrencei olivascens.** OLIVACEOUS FLYCATCHER.

Summer visitant; rare, if not accidental. A southern species, known from Arizona and Mexico. Taken once by Capt. P. M. Thorne, at Fort Lyon, May 11, 1883. (Auk, VI. 1889, 276.)

456. **Sayornis phœbe.** PHŒBE.

Summer visitant; rare. Comes west rarely to the eastern edge of Colorado. The only record is the one taken by Capt. P. M. Thorne at Fort Lyon, April 20, 1884. (Auk, VI. 1889, 276.)

457. **Sayornis saya.** SAY'S PHŒBE.

Summer resident; common. A bird of the plains rather than the mountains. Most common along the edge of the foothills, breeding in towns and around buildings like the eastern Phœbe, which it here replaces. Arrives early, from the middle of March to the first week in April, according to the season. Breeds on the plains and in the mountains to about 8,000 feet. Eggs are laid early in June.

459. **Contopus borealis.** OLIVE-SIDED FLYCATCHER.

Summer resident; common. Occurs in migration on the plains and in the mountains throughout the State. Breeds only in the mountains from 7,000 to 12,000 feet and is much less common breeding than in migrations. Breeds at least as far south as southern Colorado. Arrives late in May and breeds about the last of June. Departs southward in September.

462. **Contopus richardsonii.** WESTERN WOOD PEWEE.

Summer resident; common. Fairly common throughout the State as a breeder below 11,000 feet and very common in migration. In some places the most common Flycatcher. Extends eastward to Kansas. Arrives last of April and first week in May and breeds about the middle of June. It is most common during the breeding season from 7,000 feet to the pine region. Migrates south in September.

464. **Empidonax difficilis.** WESTERN FLYCATCHER.

Summer resident; common. Breeds from the plains to 10,000 feet, but is more common in the upper part of its range. Arrives late in May and nests early in July.

466. **Empidonax traillii.** TRAILL'S FLYCATCHER.

Summer resident; fairly common. More common on the plains, but occurs in the mountains to 8,000 feet, breeding throughout its range in Colorado. Arrives early in May and leaves late in September.

467. **Empidonax minimus.** LEAST FLYCATCHER.

Migratory; rare. Comes west only on the plains of Colorado and to the edge of the foothills. Has not been found higher than 6,000 feet. Arrives in May, and probably breeds, but no nests have as yet been taken.

468. **Empidonax hammondi.** HAMMOND'S FLYCATCHER.

Summer resident; common. Comes east only to the western edge of the plains. Pueblo is the most eastern record. Breeds from the plains to 8,000 feet. Arrives early in May.

469. **Empidonax wrightii.** WRIGHT'S FLYCATCHER.

Summer resident; abundant. In migration is abundant throughout the State west of the plains, and is equally common during the breeding season from 7,500 to about 10,000 feet. Arrives the last of April and the first week in May.

474a. **Otocoris alpestris leucolæma.** PALLID HORNED LARK.

Winter resident; abundant. The literature of the Horned Larks in Colorado is more mixed than that of any other bird. *Alpestris*, *cornuta*, *occidentalis* and *chrysolæma* have all been recorded for the State, but according to present ideas only *leucolæma* and *arenicola* really occur in Colorado. *Leucolæma* is the common "Snowbird" of the plains region and in the northern part of Colorado is enormously abundant from late in October until the middle of February. Only a few enter the mountains during the winter, probably not much if any above 8,000 feet. How far it passes up the mountains during migration has not yet been satisfactorily determined. Breeds north of the United States.

474c. **Otocoris alpestris arenicola.** DESERT HORNED LARK.

Resident; abundant. All of the summer Horned Larks of Colorado are *arenicola* and most of the winter birds of the southern half of the State belong here, as well as many from northern Colorado. Winters on the plains and a little ways into the mountains up to 9,000 feet, but only a few individuals above 7,000 feet. Breeds on the plains and in the mountains up to 13,000 feet. The bulk of migratory birds arrive on the plains in March and nesting begins early in April, two broods being raised. Eggs have been found as late as July 5. In the mountains nesting is from a month to two months later. Begins to leave the mountains early in October.

475. **Pica pica hudsonica.** AMERICAN MAGPIE.

Resident; common. A few visit the plains of the extreme eastern Colorado during the winter and breed nearly to the

Kansas line. They become more common westward, until at 50 miles from the foothills they are not uncommon locally along the banks of the larger streams. From the foothills through the mountains below 8,000 feet, they are very common and characteristic. A few breed as high as 11,000 feet and winter to 9,000 feet. On the plains and among the foothills nestbuilding begins in March and the earliest eggs the first week in April. Young are ready to fly the last of May. In the mountains the young scarcely leave the nest before the first of July.

478b. **Cyanocitta stelleri macrolopha.** LONG-CRESTED JAY.

Resident; common. Seldom strays far east of the foothills, but has been taken in winter by Capt. P. M. Thorne at Fort Lyon. Very common from the edge of the plains westward through the mountains. Breeds from the base of the foothills to timber-line, but seldom below 7,000 feet. Winters from the edge of the plains to nearly 10,000 feet. The upward movement from the plains begins early in May. Eggs are found the last of May and all through June. Fully fledged young are noted the last of June. The return movement begins the last of September.

480. **Aphelocoma woodhousei.** WOODHOUSE'S JAY.

Resident; common. Most common along the base of the foothills and the lower wooded mountains. Not often seen on the plains of eastern Colorado, but has been taken by Capt. P. M. Thorne at Fort Lyon from October to April. Breeds from 5,000 to 8,000 feet, and most commonly at about 6,000 feet. Eggs are laid the last of April and first week in May. Winters in the lower valleys and along the edge of the plains at about 5,000 feet. In the fall has been known to wander to 9,500 feet.

484a. **Perisoreus canadensis capitalis.** ROCKY MOUNTAIN JAY.

Resident; common. Remains near timber line all the year round. During the winter descends a few hundred feet, and occasionally a few wander down to the foothills, but the bulk remain above 9,000 feet even in the coldest weather. Breeds early, usually by the middle of April, which at that altitude of 8,000 to 11,500 feet is long before the snows cease. F. M. Drew says of this species in San Juan County, "In autumn, when on his first tour of inspection around the house, he hops along in a curious sidling manner just like a school girl in a slow hurry. White-headed, grave and sedate, he seems a very paragon of propriety, and, if you appear a suitable personage, he will be apt to give you a bit of advice. Becoming confidential, he sputters out a lot of nonsense in a manner which causes you

to think him a veritable 'whiskey Jack.' Yet, whenever he is disposed, a more bland, mind-his-own-business appearing bird will be hard to find, as also many small articles around camp after one of his visits, for his whimsical brain has a great fancy for anything which may be valuable to you, but perfectly useless to himself." (B. N. O. C. VI. 1881, 140.)

486. **Corvus corax sinuatus.** AMERICAN RAVEN.

Resident; common, locally. More particularly a bird of western Colorado, but occurs in the mountains as a not uncommon visitant. Has been taken by Capt. P. M. Thorne at Fort Lyon, and even extends occasionally east to western Kansas. Breeds throughout its range, but more commonly in the mountains at least to timber-line. Winters from the plains to about 10,000 feet. Irregular in its movements.

487. **Corvus cryptoleucus.** WHITE-NECKED RAVEN.

Resident; rare. Formerly common along the eastern base of the front range for its entire length in Colorado and from 50 to 100 miles out on the plains. Now entirely absent from much of this region. F. M. Dille found nests and eggs May 24, 1887, in Weld County, far east of the foothills. There is no other late record north of Boulder, where R. A. Campbell saw them twice in 1894, high up in the foothills. C. E. Aiken says of its range 20 years ago: "I first saw them in October, 1871, about 25 miles south of Cheyenne on the line of the Denver Pacific Railroad where a large flock was hovering over the plain. In the city of Denver I have often seen them searching for food in the less frequented streets, and about 100 miles farther south on the Fontaine Qui Bouille, I have seen immense numbers. At the latter place a flock of probably 1,000 individuals was resident during the winter of 1871-2. Although so abundant in winter, very few are to be seen in summer; the greater number either pass to the northward or become so distributed over the country as not to attract attention. * * * *C. cryptoleucus* is mainly a bird of the plains, being replaced in the mountains by the common raven. The two birds resemble each other so closely, both in notes and habits, that it is difficult to distinguish between them at a distance; the greatest apparent discrepancy being in size, though the croak of *carnivorus* is somewhat deeper and louder than that of the other. I have sometimes found them both associated in the same flock. Each succeeding year since I first saw these birds I have noticed a marked decrease in their numbers in El Paso County, Colorado. The cause of this I do not know unless it is because as the country becomes more thickly settled, the solitude they love so well is denied them."

The narrow strip of country in Colorado where they used to be most common, now contains fully three-fourths of the entire population of the State. The White-necked Raven used to breed from the plains to 6,000 feet, and there is no reason to believe that the few survivors have changed their nesting habits. Its present scarcity can be judged by the fact that of fifteen correspondents who have spent a great deal of their time in the field for the last ten years along the eastern base of the mountains from Pueblo to Cheyenne, only two have seen the bird alive.

488. **Corvus americanus.** American Crow.

Resident; common in northeastern Colorado, rare in the rest of the State. F. M. Dille says in substance of its distribution in Colorado: Breeds in considerable numbers along the courses of the South Platte and its tributaries in northeastern Colorado, although confined principally to the valley of the Platte. Have found it breeding in the near vicinity of Greeley, but from a point eight miles below the town their nests were quite abundant. Five nests found at one time on an island less than two acres in extent. Sometimes after a mild open winter, when the birds had been present in large numbers all the winter, they would disappear entirely as the breeding season approached. The earliest date of a full set of eggs is April 1, and the latest date May 23; average date April 27. One set taken May 5 on Clear Creek, Jefferson County, and once found nesting almost within the city limits of Denver. (Burns, Bull. No. 5, Wilson Ornith. Chapter Agassiz Assoc., Oberlin, Ohio.) In the vicinity of Fort Collins the present writer has found them not uncommon during the fall in quite large flocks, and a few nest along the Cache La Poudre, east of the foothills. H. G. Hoskins reports having seen seven at various times near Burlington, close to the Kansas line. Capt. P. M. Thorne saw a few at Fort Lyon, on the Arkansas river, while Drew and Morrison both record it from southwestern Colorado. Breeds from the plains to about 7,000 feet and winters on the plains.

491. **Nucifraga columbiana.** Clarke's Nutcracker.

Resident; abundant. The first eggs known to science were taken by Dennis Gale at Gold Hill March 9, 1888, at 8,500 feet; a second set at the same place April 16, 1889. B. F. Goss had before this, on May 21, 1879, found a nest with young at Fort Garland. Breeds from 7,000 to 12,000 feet, though most commonly from 9,000 to 10,000 feet. Breeds from the first half of March at 8,000 feet to the middle of April at its highest range. Only one brood: young are on the wing the latter half of May. Some remain in small parties during the rest of the summer, others gather in larger companies. W. E. D. Scott reports "enormous flocks" at Twin Lakes June 24,

1878. During the fall they wander up to at least 13,000 feet; in October begin to descend into the valleys. Most of them remain through the winter at 7,000 to 9,000 feet, but a few come down to the plains. H. G. Hoskins sent one for identification taken at Burlington, near the Kansas line, in January, 1896, and says that others have been seen there occasionally. They have also been taken as wanderers in South Dakota, western Nebraska and western Kansas. They begin the upward movement early in the spring, before most other migrants, and are almost the earliest birds to nest at 9,000 feet.

492. **Cyanocephalus cyanocephalus.** PINON JAY.

Resident; abundant, locally. In the summer the Pinon Jay deserves its name, for it breeds almost exclusively among the pinon pines from 7,000 to 8,000 feet. A few nests have been found as low as 5,000 feet and as high as 9,000. First eggs are laid the last of March and first of April, and eggs are found as late as the middle of May. Keeps in small parties during the breeding season, and in large flocks the remainder of the year. Continually changing location according to food supply. In autumn wanders far above the pinon pines to 13,000 feet. Late in October begins to descend, and spends the winter in the lower foothills and on the edge of the plains. At this season it wanders eastward across Colorado to Nebraska and Kansas. During the winters of 1889, 1890 and 1891 large flocks were seen in Finney County in southwestern Kansas. Returns to the pinon pines early in spring.

494. **Dolichonyx oryzivorus.** BOBOLINK.

Summer visitant; rare. Occurs only east of the range on the plains and at the base of the foothills. Henshaw saw three at the Huerfano crossing in May, 1873, Allen and Brewster noted one at Colorado Springs May 18, and two others were reported May 23. Prof. Wm. Osburn writes he has seen one at Loveland and there was one in the Maxwell Collection. This completes the record to date for Colorado. Not known to breed in the State. The bird commonly known in Colorado as the "Bobolink" is the Lark Bunting (*Calamospiza melanocorys*).

495. **Molothrus ater.** COWBIRD.

Summer resident; common. Confined principally to the lower regions, breeding from the plains to 8,000 feet. As common on the plains as anywhere in the Mississippi Valley. Arrives the last of March and leaves late in September.

497. **Xanthocephalus xanthocephalus.** YELLOW-HEADED BLACKBIRD.

Summer resident; common. In migration occurs throughout the State and breeds in suitable places on the plains and

among the foothills and parks to 7,500 feet. Scott found one July 20 at Twin Lakes at 9,500 feet, but did not ascertain that it nests at that altitude. Arrives about the middle of April and breeds early in June. Usually departs in September, but Capt. P. M. Thorne found one at Las Animas as late as October 17.

498. **Agelaius phœniceus.** RED-WINGED BLACKBIRD.

Summer resident; common. One of the most abundant birds on the plains in suitable places, breeding principally below 7,500 feet but occasionally up to 9,000 feet. Arrives early, usually about the middle of March and remains in flocks until the middle of May, when it pairs and breeds during the whole month of June. The bulk depart late in October; some remain a month later, and a few linger through most of the winter. During the mild winter of 1895-6 they were common even in northern Colorado, and during the winter of 1896–7 very large flocks were constantly present. It would seem probable that the presence of part of them at least was due to the increased abundance of food. Beginning in 1892, more and more sheep have been fed in the Valley of the Poudre and Big Thompson Rivers. The number during the winter of 1896–7 has reached nearly 200,000. All of these are fed on corn in open yards. The blackbirds in large numbers have made these yards their feeding grounds and have apparently derived a good share of their food from the scattered grain.

[499. **Agelaius gubernator californicus.** BICOLORED BLACKBIRD.

Has not been taken in Colorado, but one was taken by Mr. Bond at Cheyenne, Wyo., April 14, 1889. (Auk, VI. 1889, 341.) This is just over the line from Colorado and the bird must have crossed Colorado to get there. This is a Pacific Coast bird and the occurrence is of course accidental.]

501b. **Sturnella magna neglecta.** WESTERN MEADOWLARK.

Summer resident; abundant. More especially a bird of the plains, but also common in the lower mountain parks. Breeds on the plains and to 8,000 feet. Also met both in summer and fall above timber-line, but does not breed so high. Arrives early in March and breeds the latter part of May. Moves southward in October, though a few winter in southern Colorado. During the winter of 1895-6 they were not uncommon over most of the plains region of the State and also during 1896-7.

506. **Icterus spurius.** ORCHARD ORIOLE.

Summer visitant; rare, if not accidental. The only record for Colorado known to the present writer is the single specimen taken by Allen at Denver. (Bull. Mus. Comp. Zool. III. 1872, 113-183.) There seem to have been other records, but they are no longer accessible.

507. **Icterus galbula.** BALTIMORE ORIOLE.

Summer resident; rare. The first record for Colorado is that by Allen, that it is rare westward to the base of the Rocky Mountains. Aiken afterwards found it in El Paso County and there was one specimen in the Maxwell Collection. Undoubtedly breeds, though there is no record as yet of the nest having been found.

508. **Icterus bullocki.** BULLOCK'S ORIOLE.

Summer resident; abundant. More common at the western edge of the plains than the Baltimore Oriole is in the east. Breeds abundantly on the plains and in all the mountain region below 10,000 feet. Arrives early in May and breeds late in June. Departs in September, though Beckham saw two at Pueblo as late as October 24.

509. **Scolecophagus carolinus.** RUSTY BLACKBIRD.

Migratory; rare, if not accidental. A pair were shot near Denver December 17, 1883. (H. G. Smith, Auk, III. 1886, 284.) Prof. Wm. Osburn took one at Loveland November, 1889. (Science XXII. 1893, 212.) These are the only authentic records for Colorado. It has been several other times reported, but was evidently mistaken for Brewer's Blackbird.

510. **Scolecophagus cyanocephalus.** BREWER'S BLACKBIRD.

Summer resident; abundant. Occurs throughout the State, breeding from the plains to 10,000 feet. Arrives on the plains the middle of April, and journeys upward as fast as open marshes appear. Nests the last of May. In August and September large flocks ascend 3,000 feet above their breeding grounds and swarm over the country above timber-line to 13,000 feet. Retire in October and are common on the plains for a month longer. A few remain through the winter in the lower portions of the State.

511b. **Quiscalus quiscula æneus.** BRONZED GRACKLE.

Summer resident; not uncommon locally. Only in eastern Colorado to the base of the Rocky Mountains. Henshaw found it rather numerous at Denver; just about to build May 14. The first arrived at Burlington, Colorado, May 9, 1896. Capt. P. M. Thorne writes that he has taken it at Fort Lyon and W. P. Lowe says that it breeds near Pueblo. There is no Colorado record of its breeding above 5,000 feet.

514a. **Coccothraustes vespertinus montanus.** WESTERN EVENING GROSBEAK.

Winter visitant; irregular and not uncommon. Is liable to occur anywhere in Colorado during the winter season. It has been seen at all times from early fall to late spring. Capt. P.

M. Thorne took one at Fort Lyon May 11, and C. F. Morrison saw a flock of 30 at Fort Lewis May 17, at an altitude of 8,000 feet. These records so late in the season, make it not improbable that it may yet be found breeding in the State. It has been noted from the plains to 10,000 feet. One was taken at Fort Collins as early as October, 1888.

515. **Pinicola enucleator.** PINE GROSBEAK.

Resident; not uncommon. Most common in late summer and in winter when the bulk are just below timber-line, but stragglers descend to the foothills and wander over the plains. Capt. P. M. Thorne saw them several times at Fort Lyon and G. F. Breninger took one at Fort Collins November 6. They breed at timber-line. Trippe found young birds fully feathered by June, before the snow was gone, while at 11,500 feet D. D. Stone saw a pair feeding young as late as July 25. (O. & O. IX. 1884, 20.)

517. **Carpodacus purpureus.** PURPLE FINCH.

Migratory; rare, if not accidental. The only certain record for Colorado of this eastern species is the following from A. W. Anthony, who writes: "I have a female, which I shot November 15, 1885, near Denver. It was in company with *C. frontalis* and *cassini*."

518. **Carpodacus cassini.** CASSIN'S PURPLE FINCH.

Resident; common. Toward the latter part of November this western representative of the Purple Finch leaves its breeding grounds in the mountains and retires to the foothills and plains. It is then common in flocks along the western edge of the plains and has been taken by Capt. P. M. Thorne as far east as Fort Lyon, which is at present the most eastern record of this species. A few remain through the winter in some of the lower parks up to 7,000 feet, and a large part go south of Colorado for that season. The last of March or early in April the return movement to the mountains begins. This is almost the only species in which the summer and winter ranges are complementary. It winters from the plains to 7,000 feet and breeds from 7,000 to 10,000. By May it has worked its way up the mountains to its summer home and breeds there the latter half of June. Capt. Thorne has taken one at Fort Lyon as late as May 28. It was a female with eggs just visible to the naked eye.

519. **Carpodacus mexicanus frontalis.** HOUSE FINCH.

Resident; abundant. Originally described by Say from specimens taken near where Cañon City now stands. One of the most abundant winter birds on the plains along the base of

the foothills and breeding quite commonly in the same localities. Common in towns, breeding around the cornices of buildings and in the shades of the electric lights like the English Sparrow of the East, for which it is often taken by visitors from the portions of the United States blessed by the English importation. Rare far out on the plains, but a flock of 15 was seen in Finney County, in southwestern Kansas, January 5, 1892. Breeds on the plains and especially in the lower foothills. Less commonly in the mountains to 8,000 feet. The most eastern record of breeding anywhere is that of Capt. P. M. Thorne, who took a pair at Fort Lyon June 3, 1883. The female contained an egg with shell. He also saw one other in the fall. The height of the breeding season along the foothills is the middle of June and two broods are often reared. Eggs have been noted at Fort Collins as early as March 25 and as late as the middle of July. The most northern record noted is that of F. Bond at Cheyenne, where the first came April 14 and the nest and eggs were taken June 11, 1889. (Auk, VI. 1889, 341.)

521a. **Loxia curvirostra stricklandi.** MEXICAN CROSSBILL.

Resident; not uncommon. Under this heading are included all the Red Crossbills of Colorado, not because specimens exactly like eastern birds are not found here, but because there seems to be no satisfactory way of separating them from the western form. Occurs on the plains and the lower foothills during the winter, and breeds in the foothills and the lower mountains to about 8,000 feet. The above may be considered as the usual range, but specimens have been taken in winter at Manhattan at an altitude of 9,000 feet, and the birds have been seen in summer up to at least 11,000 feet. The breeding period is apparently quite irregular. The Red Crossbill of the east breeds in winter, and the western form must do the same at least part of the time, for C. F. Morrison found a nest and four eggs January 30, 1887, near Fort Lewis (O. & O. XIII. 1888, 70), while W. E. D. Scott at Twin Lakes found young flying June 24 that were several months old. On the contrary T. M. Trippe speaks of their breeding as late as May.

522. **Loxia leucoptera.** WHITE-WINGED CROSSBILL.

Winter visitant; rare. Only one record, that of F. M. Drew, who took one in Baker's Park, in southwestern Colorado, at 9,500 feet. (B. N. O. C. VI. 1881, 85 and 138.)

524. **Leucosticte tephrocotis.** GRAY-CROWNED LEUCOSTICTE.

Winter resident; rare. A western species breeding in the Sierra Nevada of California and probably in British America. Comes south and east in winter to Colorado, and has been taken along the eastern slope of the Rocky Mountains. To the speci-

mens already recorded may be added two taken at Fort Collins March 31. Most of the earlier records of this species really refer to *L. australis.*

524a. **Leucosticte tephrocotis littoralis.** HEPBURN'S LEUCOSTICTE.

Winter visitant; rare. Summers in British America and comes south and east in the Rocky Mountains to Colorado. There was a specimen in the Maxwell Collection; F. M. Drew gives it as occurring in the winter from 5,000 to 8,000 feet, while C. F. Morrison says that it is a winter visitant, rare on the eastern slope and common on the western. He says he has seen it both in the spring and in the fall. There is much need of more information on the occurrence in Colorado of this variety and the typical species.

525. **Leucosticte atrata.** BLACK LEUCOSTICTE.

Winter visitant; rare. Was originally described by Ridgway (Am. Sportsman IV. 1874, 24) from four specimens taken by C. E. Aiken at Cañon City in April, 1874. The present writer has seen a mounted specimen in Colorado Springs and there is one in the Maxwell Collection. All references to the birds in Colorado apparently refer to one or the other of these instances.

526. **Leucosticte australis.** BROWN-CAPPED LEUCOSTICTE.

Resident; abundant. Ranges the highest in summer of any bird in Colorado, unless it is the White-tailed Ptarmigan. Never seen below timber-line in summer and not known to nest below 12,000 feet; thence to the tops of the highest peaks. The height of the breeding season is the latter part of July. In August young and old swarm over the summits of the peaks picking insects off the snow. By the last of October or early in November, they descend to timber-line and remain there through the winter except as they are driven a little lower by the severest storms. At the same time a few come into the lower valleys almost to the base of the foothills.

528. **Acanthis linaria.** REDPOLL.

Winter resident; common. Arrives from the north in November and is fairly common on the plains and in the mountains to 10,000. Remains high in the mountains even when the temperature is thirty degrees below zero. More especially common in the lower foothills of the northern half of the State. Leaves for the north from the middle of March to the middle of April.

529. **Spinus tristis.** AMERICAN GOLDFINCH.

Resident; not common in winter and apparently then confined to the plains; abundant in migration; rather common

breeding on the plains and in the lower portions of the mountains. It seems to be most common during the summer on the plains and in the lower valleys. Although it enters the mountain parks and reaches 9,000-10,000 feet, it is not common above 7,000 feet. The great bulk move north and south in May and September, but their movements are quite irregular.

530. **Spinus psaltria.** ARKANSAS GOLDFINCH.

Summer resident; common. Comes as far north as the northern boundary of Colorado and breeds throughout its range in the State, on the plains and in the mountains to somewhat over 9,000 feet. It is the latest migrant, scarcely reaching northern Colorado before the middle of June. Breeds from the last of June to the middle of July. Nash found young at Pueblo just leaving the nest September 18, 1879. Migrates southward late in October and the first part of November. Is found rather less than a hundred miles east of the mountains out on the plains. Seems to be most common in central Colorado.

530a. **Spinus psaltria arizonæ.** ARIZONA GOLDFINCH.

Summer resident; not common and either local or else has not been separated by observers from typical *psaltria*. Brought into the fauna of Colorado by a specimen in the Maxwell Collection. In southwestern Colorado C. F. Morrison says that *psaltria* and *arizonæ* are about in even numbers and that after the young of *arizonæ* are out of the nest they go up into the mountains and appear again in abundance in October, stay a few weeks and retire south. A. W. Anthony writes that he has specimens from Pueblo and Colorado Springs taken in the breeding season. Prof. Wm. Osburn writes that he has two specimens he took at Loveland in the breeding season and that he also found them breeding at Golden. They can therefore be said to breed from the plains to 6,000 feet.

533. **Spinus pinus.** PINE SISKIN.

Resident; common. During migration this species is very abundant along the foothills. Retires to the mountains to breed, ranging in the summer from about 7,000 feet to timber-line. Occasionally a few nest at the base of the foothills. Some remain through the winter, but a little below timber-line, while the bulk are scattered over the lower valleys and throughout the plains.

000. **Passer domesticus.** EUROPEAN HOUSE SPARROW.

Resident; not yet abundant anywhere. This imported pest reached Colorado only a few years ago. W. P. Lowe noticed its arrival at Pueblo in February, 1895. (Nidologist, II.

1895, 90.) It had, however, been gradually approaching the mountains for several years previous. It reached Denver during the summer of 1896, and there are probably less than twenty pairs of these sparrows now (March, 1897) in that city, where in ten years from now there will be as many thousands. The Sparrow has reached the Rocky Mountains by following the lines of railroad westward. It is not rare in the towns along the Union Pacific and Burlington roads in northern Colorado, to within fifty miles of the mountains, and it is a question of but a few years before they will over-run all of the country east of the foothills. They have not increased very rapidly so far in the State. At Las Animas, on the Arkansas River, where they have been for about four years, there are probably not more than ten pairs in the town and none in the country outside the city limits. Their habits here are the same as in the east. It will be interesting to note the result of the rivalry in Colorado of this bird and the House Finch (*Carpodacus mexicanus frontalis*). This latter bird has for years occupied the place in Colorado that the English Sparrow does farther east. Over the eastern half of the United States, the English Sparrow has not had to contend with any species of habits similar to its own. In Colorado, at the base of the mountains, it meets its first real foe. Time will tell which will be victorious.

534. **Plectrophenax nivalis.** SNOWFLAKE.

Winter visitant; rare. Comes to the plains region of northeastern Colorado during the winter season, but never in large numbers and not regularly. Has been taken at Fort Collins, Loveland, Boulder and Denver. C. F. Morrison records one from La Plata County March 1. This is the only record from west of the range.

536. **Calcarius lapponicus.** LAPLAND LONGSPUR.

Winter resident; common. Enters Colorado from the north in October and remains through the winter. When it first arrives it passes up into the lower mountain parks, but in severe weather it is confined to the plains extending to southern Colorado. Breeds far north.

538. **Calcarius ornatus.** CHESTNUT-COLLARED LONGSPUR.

Summer resident, rare; winter resident, not common; in migration, common. Has been taken during the winter at Fort Collins, Loveland, Boulder, Pueblo, Fort Lyon, and Allen and Brewster saw a flock at Colorado Springs as late as May 9. No records from west of the range. Breeds regularly in Northern United States and British America. Given by Ridgway as breeding in Colorado, though the present writer can find no authority for the statement. Known to breed in Wyoming and Nebraska just over the Colorado line.

539. **Rhyncophanes mccownii.** McCown's Longspur.

Winter resident; common. One of the commonest winter birds on the whole plains region of Colorado east of the mountains. Found by Allen and Brewster at Colorado Springs as late as May 9. Reaches southern Colorado in the fall about the first of October. McCown's Longspur has been several times given as breeding in Colorado. This is very likely true, but the present writer has been unable to find a single authentic record of its occurrence in the State during the summer. Allen found it breeding abundantly at Cheyenne, Wyo., only a few miles north of Colorado.

540a. **Poocætes gramineus confinis.** Western Vesper Sparrow.

Summer resident; abundant. During migration one of the most abundant of birds on the plains and in the foothills. It breeds sparingly on the plains of eastern Colorado, more commonly on the plains nearer the foothills, and abundantly at the base of the mountains. It is still a common breeder to 9,000 feet, and occasionally to 12,000. Arrives in southern Colorado the middle of April, and reaches the mountain parks early in May.

542b. **Ammodramus sandwichensis alaudinus.** Western Savanna Sparrow.

Summer resident; common. In migration it is very abundant and many remain to breed. On the plains they can hardly be called other than a migrant, but from the base of the foothills through the mountains it is not an uncommon breeder up to nearly 12,000 feet. Arrives early in April and remains until the middle of October. All the specimens taken by Capt. P. M. Thorne at Fort Lyon were typical *alaudinus*.

545. **Ammodramus bairdii.** Baird's Sparrow.

Migratory; not common. Has been taken at various places along the eastern edge of the mountains and on the plains during spring and fall migration. The only record west of the Front Range is the one taken by Aiken in the San Luis Valley August 22, 1874. But since it is common in Arizona during the fall and winter, it undoubtedly crosses western Colorado during its migrations. Not known to breed in the State.

546a. **Ammodramus savannarum perpallidus.** Western Grasshopper Sparrow.

Summer resident; not uncommon, but seldom noticed. Breeds mostly on the plains or in the lower foothills. Arrives the middle of April.

552a. **Chondestes grammacus strigatus.** WESTERN LARK SPARROW.

Summer resident; common. Breeds commonly over all the plains of eastern and western Colorado, and in the mountain parks less commonly to 10,000 feet. Arrives the last of April and breeds late in May.

553. **Zonotrichia querula.** HARRIS'S SPARROW.

Migratory; rare. Only one record for the State. One taken by C. W. Beckham at Pueblo, October 29, 1886. (Auk, IV. 1887, 120.) In the Auk, XI. 1894, 182, the present writer recorded a specimen at Colorado Springs that he was assured had been taken in the vicinity. Further investigation has revealed the fact that the specimen was obtained in Texas.

554. **Zonotrichia leucophrys.** WHITE-CROWNED SPARROW.

Summer resident; abundant. During migration one of the commonest birds. Arrives in April and spends two months in working up to timber-line. F. M. Drew has noted the queer fact of their changing location between the first and second brood. He says that they are common and breed during June in Baker's Park in San Juan County at about 8,000 feet; that most of them then leave the Park and are numerous among the stunted bushes above timber-line where they raise a second brood. In September they return to the park and linger until October. (B. N. O. C. VI. 1881, 138.) Breeds most abundantly from 10,000 to 11,000 feet and July is the height of the breeding season. Known to breed as high as 12,500 feet. The last of the migrants leaves the lower valleys about the first of June. On their return the last leaves the State in November.

554a. **Zonotrichia leucophrys intermedia.** INTERMEDIATE SPARROW.

Migratory; common. Arrives from the last of March to the middle of April, and on its northward journey keeps near the level of the plains. It is abundant in the foothills and lower portions of western Colorado and is not uncommon east to the Kansas line. The bulk leave the State in April and the last about the middle of May. On their southward journey they are a little later than the White-crowned Sparrow. Breed north of the United States.

557. **Zonotrichia coronata.** GOLDEN-CROWNED SPARROW.

Winter visitant; accidental. A Pacific Coast species, known once from Colorado. Prof. Wm. Osburn says that a small flock spent the winter of 1889 in the thickets along the Big Thompson. One was shot February 23. (Science, XXII. 1893, 212.)

558. **Zonotrichia albicollis.** White-throated Sparrow.

Migratory; rare. The only records for Colorado of this eastern species are the one shot by C. W. Beckham at Pueblo, October 24, 1886 (Auk, IV. 1887, 120), and the one taken by H. G. Smith near Denver October 5, 1892. (Nidologist, III. 1896-7, 76.) Since it has been taken as a rare migrant on the Platte in Wyoming and is known to breed in northern Wyoming, it is probable that more pass through Colorado in migration than would be supposed from the meagreness of the record.

559a. **Spizella monticola ochracea.** Western Tree Sparrow.

Winter resident; common. Spends the winter on the plains and in the lower parts of the mountains. Common to 7,000 feet and occasionally to 9,000. Arrives from the north about the middle of October and becomes common early in November. The bulk leave in April and the last by the first of May. The western form is found over all the plains to Kansas.

560. **Spizella socialis.** Chipping Sparrow.

Summer resident, rare; in migration, not uncommon. The typical Chippy of the east comes into Colorado as far as the foothills of the Rocky Mountains. There is no authentic record as high as 6,000 feet. The western variety, *arizonæ*, is the prevailing form at the base of the mountains and for several miles out on the plains. There is need of much more information as to the relative distribution of the two birds in eastern Colorado. Though not uncommon during migration, the typical form must be quite rare as a breeder. There is indeed no unquestionable record of its breeding in Colorado and it is entered above as a summer resident on the strength of its known breeding to the east and the north in Kansas and Nebraska. Arrives in northern Colorado the last of April.

560a. **Spizella socialis arizonæ.** Western Chipping Sparrow.

Summer resident; abundant. Especially common along the foothills in migration. Allen and Brewster mention a flock of at least 1,000 birds seen May 13 at Colorado Springs. Not known to breed far out on the plains, but it breeds from the base of the foothills to nearly 10,000 feet. Breeds most commonly from 6,000 to 7,000 feet. Arrives the middle of April and most go into the foothills by the middle of May. Breeds the middle of June. Leaves the State the latter part of October. Six specimens taken by Capt. P. M. Thorne at Fort Lyon have been identified as this variety, but they are known there only during migration.

561. **Spizella pallida.** CLAY-COLORED SPARROW.

Summer resident; not uncommon. Appears not to be common anywhere in Colorado, but is scattered over all of the State east of the mountains. Breeds in north-central Colorado on the plains and at the base of the foothills, but the southern limit of its breeding range in the State has not been satisfactorily determined. V. L. Kellogg shot one in Estes Park August 10. (Trans. Kans. Acad. Science, XII. 1889–90, 86). This is the only record for the mountains and is probably a bird that had wandered upward after the breeding season. Arrives the last of April and leaves late in September.

562. **Spizella breweri.** BREWER'S SPARROW.

Summer resident; not uncommon. Arrives from the middle of April to the first of May. Most common in migration the first half of May. Rather more common in the southern half of the State. Breeds throughout its range from the plains to 8,000 feet. Principally a western species, but Capt. P. M. Thorne took it as far east as Fort Lyon.

566. **Junco aikeni.** WHITE-WINGED JUNCO.

Winter resident; common. Winters on the plains and in the mountains to at least 8,000 feet. The commonest Snowbird in the mountains in the winter. According to C. E. Aiken, "the first stragglers from the north do not make their appearance till about the 5th of October, [this is on the plains of El Paso County. In the mountains they do not arrive until late in October or early November,] and then in gradually increasing numbers till the first of December, when they come in large flocks, the last to arrive being the old and fully plumaged males. While many of the females and young birds proceed farther to the south, the greater number of the adult males winter at some point farther to the north than El Paso County, as of the whole number seen during the winter only about two-fifths are males. Early in February the old birds begin to start northward, the general migration being delayed about a month." Has been taken in Colorado as late as April 11. Breeds in northern Wyoming.

567. **Junco hyemalis.** SLATE-COLORED JUNCO.

Winter resident; not common. The typical *hyemalis* comes west to the Rocky Mountains as a rather rare visitor. If it is ever common, it is during spring migration from the last of March to the middle of April; less common during fall migration in November; still less common during the winter season. Winters on the plains and in the foothills to 7,000 feet. During spring migration goes a 1,000 feet higher. Not

known to breed in the State, which is somewhat strange considering how far south it breeds in the mountains of eastern United States.

567b. **Junco hyemalis connectens.** SHUFELDT'S JUNCO.

Winter resident; abundant. Great numbers winter in southern Colorado, where F. M. Drew says that they appear first at timber line in September; later, stragglers come down and mix with *caniceps* and by October have taken full possession. When severe winter weather begins they pass lower down. (B. N. O. C. VI. 1881, 138.) They remain in numbers throughout the winter as far north as central Colorado, and are not an uncommon winter resident nearly to the northern boundary. Very common in migration during November and April. Extend eastward to Kansas.

568. **Junco mearnsi.** PINK-SIDED JUNCO.

Winter resident; common. In middle Colorado, during the winter, one of the most common Juncos, especially on the plains at the base of the foothills. Arrives rather late in the fall, and is most numerous during the spring migration. At this latter season it is principally a bird of the mountains from 6,000 to 10,000 feet. The period of greatest numbers is about the first of April. The last of the migrating Juncos to leave, remaining until the last of April. Aiken once saw females in El Paso County as late as May 4. Extends east on the plains as far as Fort Lyon, where it has been taken by Capt. P. M. Thorne.

568. 1. **Junco annectens.** RIDGWAY'S JUNCO.

Winter visitant; rare. One was taken by R. C. McGregor at Boulder November 25, 1892, associated with *mearnsi*, *caniceps*, *aikeni*, and *connectens*. (Auk, X, 1893, 205.)

569. **Junco caniceps.** GRAY-HEADED JUNCO.

Resident; abundant. The only Junco at present known to breed in Colorado. The bulk winter south of the State, but a few remain on the plains and the lowest valleys of the mountains from November to April. In southwestern Colorado F. M. Drew says that they are very abundant in summer from 7,500 to 12,000 feet, raising two and perhaps three broods. Large young out of the nest taken June 26, and nest with fresh eggs a month later; young birds September 25. The commonest summer bird, taking the place of the Chippy of the east. Leave the first of November just as *oregonus* [=*connectens*] becomes plentiful. (B. N. O. C. VI. 1881, 138.) Farther north, in Clear Creek County, where it does not winter, T. M. Trippe, in "Birds of the Northwest," says that it arrives the middle or

latter part of March, two or three weeks before the other varieties leave. Works upward as the snow leaves, and by the middle of June has left the region below 8,000 feet. Breeds abundantly from the upper limit of shrubs to 1,000 feet below timberline, and less commonly down to 8,500, and occasionally at 7,000 feet. In October descends to lower valleys and soon leaves the county. D. D. Stone found fresh eggs from June 8 to July 18 at 10,000 feet in Gunnison County. (O. & O. IX. 1884, 20.) Common on the plains during spring and fall migration, remaining in the spring usually to the first of May, and rarely as late as June 1. Capt. P. M. Thorne took it as far east as Fort Lyon.

570a. **Junco phæonotus dorsalis.** RED-BACKED JUNCO.

Migratory; rare. The only record for Colorado is that of Chas. F. Morrison who says that they were abundant during the spring of 1887 at Fort Lewis in the extreme southwestern corner of Colorado. (O. & O. XV. 1890, 36.) This is the resident and abundant form just south of the Colorado line and it would be strange if some did not enter the State. It has been entered above as migratory according to the record, but if it occurs as anything more than an accidental visitant, it must breed.

573. **Amphispiza bilineata.** BLACK-THROATED SPARROW.

Summer resident; not uncommon, locally. A southern and western species barely reaching to Colorado and found only in the southwestern portion. Abundant a little south of Colorado in Arizona. The only record east of the range and probably accidental, is one taken by C. E. Aiken, July 26, 1872, in a mountain park near Cañon City.

574a. **Amphispiza belli nevadensis.** SAGE SPARROW.

Summer resident; abundant. Quite common on the sagebrush plains of western and southwestern Colorado. Comes east as far as San Luis Park, where Henshaw found it not uncommon up to 8,000 feet.

581. **Melospiza fasciata.** SONG SPARROW.

Migratory; rare. Among five Song Sparrows taken by Capt. P. M. Thorne at Fort Lyon, and now in the Field Columbian Museum at Chicago, is one typical *fasciata*, the other four being *montana*. *Fasciata* is the common form found throughout Kansas and Nebraska, and in view of the above record it is probable that a few migrate across the plains of the extreme eastern Colorado and may not unlikely breed in northeastern Colorado.

581b. **Melospiza fasciata montana.** MOUNTAIN SONG SPARROW.

Summer resident; common. It might be called resident, since a few breed on the plains and in mild winters a few remain all the year. Common throughout the State in migration and not uncommon as a breeder from the plains to 8,000 feet. Breeds more commonly at the upper limit of its range. Arrives late in March.

583. **Melospiza lincolni.** LINCOLN'S SPARROW.

Summer resident; common. An abundant species in migration both on the plains and in the mountains. Breeds in the mountains from 7,000 feet to timber-line and occasionally to the base of the foothills. Most common during the summer months at or near timber-line. Arrives last of April or early in May and by the last of May has left the plains for the north or gone up into the mountains. Breeds late in June and descends to the plains again the first half of October, leaving the State about the first of November.

585c. **Passerella iliaca schistacea.** SLATE-COLORED SPARROW.

Summer resident; rare. The status of this species as a Colorado bird is very unsatisfactory. Ridgway makes the unequivocable statement that it breeds in Colorado along "streams of the mountain parks." (Bull. Essex Inst. V. 1873, 183.) The basis for this statement cannot now be ascertained and it has not been confirmed by later observers. Indeed this is the only record the bird has for Colorado. It has been commonly supposed that the type specimen of this variety was taken in Colorado and this is so stated by Bendire in his Life Histories of North American Birds. The present writer is indebted to Prof. T. S. Palmer, of the Department of Agriculture at Washington, for the information that the specimen in question was taken by Lieut. Bryan's party July 19, 1859, in Nebraska, about 20 miles east of the Colorado line.

588. **Pipilo maculatus arcticus.** ARCTIC TOWHEE.

Winter resident; not uncommon. It is somewhat difficult to draw the line between *arcticus* and *megalonyx* in Colorado. According to the best light obtainable at the present time, those birds should be referred to *arcticus* that occur on the plains east of the mountains during fall, winter and spring as migrants from the north; and that all breeding birds should be referred to *megalonyx*. *Arcticus* arrives from the north early in October and remains until April. Occurs from middle Kansas to the eastern base of the Rocky Mountains.

588a. **Pipilo maculatus megalonyx.** SPURRED TOWHEE.

Summer resident; common. Arrives last of March to the middle of April and by the middle of May has reached its upper summer limit at 9,000 feet. Breeds from the base of the eastern foothills westward. Eggs are laid from the last of May through June. Goes south late in September. So far as known extends even in migration but a few miles out on the plains.

590. **Oreospiza chlorura.** GREEN-TAILED TOWHEE.

Summer resident; common. Occurs throughout all of western Colorado and common for a few miles out on the plains. Has been taken by Capt. P. M. Thorne as far east as Fort Lyon. Arrives the last of April and early part of May; ascends into the mountains to the limit of trees. Breeds in all its range but most commonly about 8,000 feet; nests in May and often raises two broods. Leaves the State in October.

591. **Pipilo fuscus mesoleucus.** CANON TOWHEE.

Resident; common, locally. All the records for the State come from the Arkansas Valley. It is a common resident in Pueblo County nesting in juniper and sometimes cactus bushes. Most common on the plains and lower foothills but occurs sparingly up to 10,000 feet. Breeds the latter part of April. The above statements are from the notes of Beckham, Lowe and Nash, who have made a special study of the birds of the Arkansas Valley. Occurs regularly and abundantly south and southwest of Colorado.

592. **Pipilo aberti.** ABERT'S TOWHEE.

Summer resident; rare. There is no record for Colorado but that of Henshaw, who says: "Though no specimens were secured, pretty good evidence of the presence of this species at the alkali lakes northwest of Fort Garland, Colo., was obtained by the discovery of a nest, about June 25, 1873, containing two eggs, which a careful comparison with specimens in the Smithsonian Institution satisfies me, must have belonged to this bird. It had evidently been deserted a short time before." (Henshaw, 1875, 306.) In New Mexico and Arizona this species is abundant.

593. **Cardinalis cardinalis.** CARDINAL.

Winter visitant; rare, if not accidental. A. W. Anthony writes that one was taken below Denver, December 5, 1883. It is a rare resident in western Kansas and common southward.

596. **Zamelodia melanocephala.** BLACK-HEADED GROSBEAK.

Summer resident; common. Occurs throughout the whole of Colorado from the plains to 8,000 feet, and breeds every-

where. Arrives about the middle of May and breeds about the first of June. Departs south in September. W. P. Lowe reports seeing several in the Wet Mountains at an altitude of 10,000 feet.

597a. **Guiraca cærulea eurhyncha.** WESTERN BLUE GROSBEAK.

Summer resident; not uncommon, locally. A southern species, known from South Dakota, southwesterly across southeastern Colorado to southern Utah. All the records for Colorado come from the Arkansas Valley, where it is reported by Aiken, Lowe and Beckham as not uncommon and breeding at Pueblo. Capt. P. M. Thorne also saw two at Fort Lyon. Arrives late in May.

598. **Passerina cyanea.** INDIGO BUNTING.

Summer visitant; rare, if not accidental. An eastern species, coming regularly only to eastern Kansas. Taken twice in Colorado; once by C. E. Aiken in El Paso County, while the other specimen is in the Maxwell Collection, without any record as to when or where it was taken.

599. **Passerina amœna.** LAZULI BUNTING.

Summer resident; abundant. From the plains to the lower foothills, an abundant and characteristic species, breeding everywhere. A few breed at 7,000 feet and occasionally wander a thousand feet higher. Taken by Capt. P. M. Thorne at Fort Lyon and breeds east to western Kansas. Arrives early in May and breeds about the middle of June. One was taken by Prof. C. P. Gillette July 7, 1896, on Little Beaver Creek, Larimer County, at an altitude of 9,100 feet.

604. **Spiza americana.** DICKCISSEL.

Summer resident; rare. Occurs only on the plains and at the foothills east of the Rocky Mountains. A few pairs spend the summer each year on the plains near Fort Collins and they have been noted at various places from there to Fort Lyon where Capt. P. M. Thorne saw six June 22, 1884. In five years residence there, these were the only ones seen. Farther east in Kansas it becomes one of the commonest birds.

605. **Calamospiza melanocorys.** LARK BUNTING.

Summer resident; abundant. The most common summer bird on the plains. Locally known as the "Bobolink." Much more common east than west of the mountains. Breeds on the plains and in the foothills to about the limit of cultivated fields at 8,000 feet. Becomes rapidly less numerous after passing the lowest foothills. Arrives the first week in May spreading over

all the plains region in a few days. The females arrive about a week later than the males. Begins to migrate south late in August and disappears the latter part of September.

607. **Piranga ludoviciana.** LOUISIANA TANAGER.

Summer resident; common. In migration occurs on the plains for 50 to 75 miles east of the foothills. It is common at Pueblo, but 80 miles east of there at Fort Lyon, Capt. P. M. Thorne did not see one in five years' residence. It was taken however at Finney County, southwest Kansas as a rare straggler, May 20 and June 1, 1893. During the breeding season it deserts the plains and is common at 10,000 feet. Few breed below 7,500 but some as low as 6,000 feet. Arrives on the plains the middle of May and moves into the mountains early in June. Breeds the last of June and remains in the mountains until September. The last leave the State late in October.

[608. **Piranga erythromelas.** SCARLET TANAGER.

A male was taken by Mr. Bond at Cheyenne, Wyo., May 28, 1889. (Auk, VI. 1889, 341.) The bird is common a little farther east, but has no Colorado record. This individual may have crossed Colorado to reach Cheyenne, which is just over the Colorado line, or it may have passed westward up the Platte].

610a. **Piranga rubra cooperi.** COOPER'S TANAGER.

Summer visitant; rare or accidental. A southern species common in New Mexico and Arizona, but scarcely coming north to Colorado. Only one specimen known, taken by Henshaw at Denver, May 10, 1873. (Henshaw, 1875, 239.)

611. **Progne subis.** PURPLE MARTIN.

Summer resident; not common and local. Appears to be almost entirely lacking along the eastern slope of the Rocky Mountains and the plains at their base. As common in Utah as in the east and not uncommon in the extreme western part of Colorado. Again to the eastward, it is common in Kansas and extends a little way across the border into Colorado. In eastern Colorado, it arrives the last week of April and remains to breed on the plains. In western Colorado it arrives about the same time, but goes into the mountains for the summer, breeding from 6,000 to 8,000 feet; farther west in Utah it breeds both in towns on the plains and in the mountains.

612. **Petrochelidon lunifrons.** CLIFF SWALLOW.

Summer resident; abundant. Breeds everywhere from the plains to 10,000 feet, nesting both on cliffs and under eaves. Arrives the last of April and first half of May. Breeds late in June. There is so long a time between its arrival and the beginning of nest building that breeding occurs at about the same time on the plains and in the mountains over the whole of Colorado.

613. **Chelidon erythrogastra.** BARN SWALLOW.

Summer resident; common. Breeds on the plains and in the mountains to 10,000 feet, but nowhere in such numbers as *lunifrons* or *thalassina*. Arrives the last of April. Breeds in June and often raises two broods. H. G. Smith says that the same pair returned to his place in Denver to breed for fifteen consecutive years.

614. **Tachycineta bicolor.** TREE SWALLOW.

Summer resident; not uncommon, but rare for a Swallow. Breeds occasionally on the plains and more frequently in the mountains to 10,000 feet. Arrives in April and breeds from the last of May to the last of June. Departs in September.

615. **Tachycineta thalassina.** VIOLET-GREEN SWALLOW.

Summer resident; abundant, locally. Throughout western Colorado and east to the edge of the plains. A few breed on the plains, but more commonly from 6,000 to 10,500 feet. Arrives from the first week in May on the plains to the last of the month in the mountains. Begins laying late in June to the first of July. Deserts the higher regions in August and the lower early in September.

616. **Clivicola riparia.** BANK SWALLOW.

Summer resident; rare. The rarest Swallow in Colorado. Arrives the last of April and breeds on the plains and at the base of the foothills.

617. **Stelgidopteryx serripennis.** ROUGH-WINGED SWALLOW.

Summer resident; not uncommon. Much more common than the Bank Swallow. Breeds near streams on the plains and in the lower portions of the mountains below 7,500 feet. Arrives early in May.

618. **Ampelis garrulus.** BOHEMIAN WAXWING.

Winter resident; not uncommon. Irregular in its movements and numbers. Has been noted at one time or another from most of the State; rather rare on the plains and more common in the mountains to at least 8,000 feet. Breeds north of the United States and reaches southern Colorado in November; remaining through the winter. The bulk leave late in February or early March. Has been taken at Denver by H. G. Smith as late as March 22, 1884.

619. **Ampelis cedrorum.** CEDAR WAXWING.

Resident; not common; local and irregular. Scattered over the lower portions of the State during the fall, winter and spring. Breeds on the plains and in the mountains to about 9,000 feet. Breeds about the middle of June.

621. **Lanius borealis.** NORTHERN SHRIKE.

Winter resident; common. Breeds north of the United States and comes south to Colorado in October. Makes its first appearance high up on the mountains above timber-line and later descends to the plains. Quite common at the western edge of the plains where food, in the shape of Shore Larks, is abundant. Also winters less commonly in the mountain parks to 9,500 feet. Departs northward in March.

622a. **Lanius ludovicianus excubitorides.** WHITE-RUMPED SHRIKE.

Summer resident; common. Arrives from the south soon after the Northern Shrike leaves, early in April, and is quite common through the summer on the plains. Less common in the mountains to about 9,500 feet. On the plains breeds late in May and sometimes raises two broods.

624. **Vireo olivaceus.** RED-EYED VIREO.

Summer resident; rare. An eastern species coming only west to the base of the foothills. Allen took it in the mountains at 11,000 feet, but this must be considered as an accidental occurrence. Arrives late in May and leaves in September. Capt. P. M. Thorne took it at three different times at Fort Lyon, where he marks it as tolerably common. Prof. Wm. Osburn saw but one at Loveland in several years of active collecting. There are both male and female in the Maxwell Collection.

627. **Vireo gilvus.** WARBLING VIREO.

Summer resident; common. The most common Vireo in Colorado. Arrives on the plains the first week in May and at its upper range in the mountains by the last of the month. Breeds sparingly on the plains and abundantly in the mountains; almost as common at 10,000 feet in summer as lower down. Breeds about the first of July.

629a. **Vireo solitarius cassinii.** CASSIN'S VIREO.

Rare or accidental summer visitant; not known to breed. A southwestern species not regularly reaching north to Colorado. There was a specimen in the Maxwell Collection that may or may not have been taken in this State. Mr. H. G. Smith took one near Denver May 13, 1888, and the specimen was identified by Ridgway. (Nidologist, III. 1896-7, 76.)

629b. **Vireo solitarius plumbeus.** PLUMBEOUS VIREO.

Summer resident; common. Extends east at least to the base of the mountains and a few miles out on the plains. Arrives early in May. Breeds in the foothills and among the mountains to rather over 9,000 feet. Nests among the pines, but in migration occurs everywhere.

636. **Mniotilta varia.** BLACK AND WHITE WARBLER.

Summer visitant; rare. An eastern species scarcely coming west of central Kansas. Has been taken twice, once by Minot at Boulder, June 1, 1880 (B. C. N. O. V. 1880, 223), and Geo. F. Breninger writes that he took one at Table Rock, on the Divide between Denver and Colorado Springs. Not known to breed in Colorado, though breeding in corresponding latitudes in Kansas.

644. **Helminthophila virginiæ.** VIRGINIA'S WARBLER.

Summer resident; common. Most common at the limit of its eastern extension at the base of the foothills and though so common there it is not known a few miles out on the plains at Pueblo. This is one of the few exceptions to the rule that any western species found in the foothills follows down the Arkansas at least as far as Pueblo. Through western Colorado it is abundant in migration and in many places is the most common Warbler during the breeding season. Breeds very commonly along the eastern slope of the Rocky Mountains from the foothills to 7,500 feet. Arrives the first week in May and breeds about the middle of June. Leaves the State late in September.

646. **Helminthophila celata.** ORANGE-CROWNED WARBLER.

Summer resident; not uncommon. Quite common in migration, extending over the plains and a little ways into the mountains. Over the former it is known only as a migrant; in the latter it breeds from about 6,000 to 9,000 feet, but is rare above 8,000 feet. Arrives the first week in May and leaves late in September or early October.

646a. **Helminthophila celata lutescens.** LUTESCENT WARBLER.

Summer resident; not uncommon. The western form of the Orange-crowned Warbler, coming east as far as the eastern base of the Rocky Mountains at Denver and at Colorado Springs. Movements and habits so far as known the same as the Orange-crowned Warbler. There is no doubt that the two forms occur in Colorado, and that in general one inhabits eastern Colorado and the other western, but whether their habitats meet or overlap, and their relative distribution in the mountains during the breeding season, are points that need further elucidation.

647. **Helminthophila peregrina.** TENNESSEE WARBLER.

Migratory; rare. Only known from eastern Colorado at the base of the Rocky Mountains, where it has been taken in El Paso County by Aiken, at Boulder by Minot, at Loveland by

Osburn and Smith, and there are both male and female in the Maxwell Collection. Passes through Colorado the latter half of May.

648. **Compsothlypis americana.** PARULA WARBLER.

Summer resident; rare. An eastern species coming scarcely west to the foothills of the Rocky Mountains. Has never been taken in the northern part of Colorado, but from Colorado Springs south and southeast a few occur each summer. Arrives early in May.

652. **Dendroica æstiva.** YELLOW WARBLER.

Summer resident; abundant. The commonest Warbler that breeds on the plains. Arrives the first week in May and breeds both on the plains and in the mountains to 8,000 feet, though rather more common at the lower altitudes.

652a. **Dendroica æstiva sonorana.** SONORA YELLOW WARBLER.

Summer resident; probably common. To the southwestward the eastern form of the Yellow Warbler shades into the Sonora variety. It is not yet known with definiteness, where the dividing line should be drawn. In his original description of *sonorana*, Mr. Brewster says that a Colorado specimen is a fair intermediate between *sonorana* and *morcomi*. (Auk, V. 1888, 139.) A specimen taken by Capt. P. M. Thorne at Fort Lyon, Mr. Brewster marks as not typical but nearest *sonorana*. If this view is finally adopted, it will probably include under *sonorana* many of the Yellow Warblers of southern and especially southwestern Colorado.

654. **Dendroica cærulescens.** BLACK-THROATED BLUE WARBLER.

Migratory; rare. The only Colorado record is that of a specimen taken in the vicinity of Denver by Mr. H. G. Smith, May 24, 1888. (Nidologist, III. 1896-7, 76.) In the Auk, XI. 1894, 182, the present writer recorded a specimen at Colorado Springs that he was assured had been shot in that vicinity. Further investigation has shown that the bird came from without the State.

655. **Dendroica coronata.** MYRTLE WARBLER.

Migratory; not uncommon. Arrives the last of April or early in May and is not uncommon for two or three weeks along the base of the foothills and on the plains. Migrates from ten days to two weeks ahead of *auduboni*, but in May the two species are often found together. A few go into the foothills to 9,000 feet. Scarcely known west of the Rocky Mountains. The last leave

by the middle of May. Breeds from the northern United States northward. Much less common during fall migration.

656. **Dendroica auduboni.** AUDUBON'S WARBLER.

Summer resident; abundant. During the summer this is the most common Warbler among the higher mountains. Arrives on the plains early in May and in migration is very common at the western edge of the plains and less and less common eastward to western Kansas. Is known on the plains only as a migrant. Extends into the mountains the middle of May and by the last of the month has reached the upper limit of its range. Breeds from 7,500 to 11,000 feet and is most common above 9,000 feet. Laying begins from the last of May in southwestern Colorado to the middle of June in the north-central part of the State. The last leaves the plains for the mountains the last week in May. Begins to return in August; during September is common in the lower parks and appears on the plains. Leaves the State in October.

657. **Dendroica maculosa.** MAGNOLIA WARBLER.

Migratory; rare. In migration extends westward to the western edge of the plains, where one was taken by Henshaw at Denver May 17, 1873. Capt. P. M. Thorne has also taken one at Fort Lyon May 17, 1884. Breeds in the northern United States and northward.

658. **Dendroica rara.** CERULEAN WARBLER.

Migratory; rare. The only Colorado record is the one seen by Henshaw at Denver May 17, 1873. An eastern species common in Kansas during migration and rarely breeding in that State.

[659. **Dendroica pensylvanica.** CHESTNUT-SIDED WARBLER.

One was taken by Mr. Bond at Cheyenne, Wyo., May 23, 1889. (Auk, VI. 1889, 341.) This is only just over the line from Colorado, and the bird, which is a common species a little farther east, may have crossed Colorado or may have passed westward up the Platte River.]

661. **Dendroica striata.** BLACK-POLL WARBLER.

Summer resident; rare. An eastern species coming rarely but regularly west to the Rocky Mountains. Occasionally common in migration, both on the plains and at the base of the foothills. The only record of breeding in Colorado, and the most southern in the United States, is that of H. D. Minot who found it as a summer resident at Seven Lakes, near Manitou, at an altitude of 11,000 feet. (B. N. O. C. V. 1880, 223.) Reaches Colorado about the middle of May.

664. **Dendroica graciæ.** GRACE'S WARBLER.

Summer resident; common in extreme southwestern Colorado. A southwestern species reaching its extreme northern

limit in southern Colorado. F. M. Drew says that it is common on the tributaries of the San Juan River, breeding in the pines from 6,000 to 7,000 feet. (B. N. O. C. VI. 1881, 85.) In La Plata County, Chas. F. Morrison found them not common and took eggs in May at 8,500 feet. A most surprising occurrence was the appearance of a small flock of these birds in the spring of 1889 at Loveland, where they were seen by Prof. Wm. Osburn and one secured April 25. At the request of the present writer, the specimen has been lately re-examined and there is no doubt of the identification.

665. **Dendroica nigrescens.** BLACK-THROATED GRAY WARBLER.

Summer resident; rare. A western species coming north to north central Colorado and east to the base of the foothills, but never common. Arrives early in May. Has been taken at Silverton, 9,500 feet, May 30, and at Idaho Springs, 7,800 feet, May 23. Its breeding range in the State has not been satisfactorily determined.

668. **Dendroica townsendi.** TOWNSEND'S WARBLER.

Summer resident; not uncommon. A western species coming east regularly to the base of the foothills and a few miles out on the plains. The most eastern record is that of Capt. P. M. Thorne at Fort Lyon, one only seen, May 26, 1883. Rare on the plains at any time and then only as a migrant, passing north the latter part of May and returning in September. In the mountains it is rather common during the fall migration from 7,500 to 10,000 feet. Rather rare in summer, breeding from 5,500 to 8,000 feet in western Colorado. No record of its breeding east of the Rocky Mountains.

674. **Seiurus aurocapillus.** OVEN-BIRD.

Summer visitant; rare or accidental. The only fully authentic record for Colorado is the single specimen taken by Dr. C. Wernigk at Denver in June, 1862. It will probably yet be found as a rare visitant to northeastern Colorado, since it is not uncommon a short distance from the State line.

675a. **Seiurus noveboracensis notabilis.** GRINNELL'S WATER THRUSH.

Migratory; rare. Recorded from Denver, Boulder, Nederland, Loveland and Fort Lyon, i. e., from the plains to 8,000 feet. Passes through Colorado the latter part of May. Not known to breed.

680. **Geothlypis macgillivrayi.** MACGILLIVRAY'S WARBLER.

Summer resident; common. Arrives early in May and breeds from the base of the foothills to 9,000 feet. Laying begins

the latter part of June. Leaves the mountains in August and the State in September. One of the most common Warblers of western Colorado. Comes east commonly to the edge of the plains and rarely to Fort Lyon, where it was seen occasionally and taken by Capt. P. M. Thorne.

681a. **Geothlypis trichas occidentalis.** WESTERN YELLOW-THROAT.

Summer resident; common. Almost confined to the plains, where it is common in migration and not uncommon as a breeder. Is found on both sides of the range, but only in the lowest portions scarcely coming up to 6,000 feet; much less common in western Colorado than eastern. Arrives the first week in May, but sometimes reaches northern Colorado by the middle of April.

683. **Icteria virens.** YELLOW-BREASTED CHAT.

Summer visitant; accidental. The typical form from the east was found by Say in the Rocky Mountains at the head-waters of the Arkansas. (B. B. and R. Birds of N. Am.)

683a. **Icteria virens longicauda.** LONG-TAILED CHAT.

Summer resident; common. Scarcely found in the mountains, but common in the lower foothills and on the plains. Does not breed above 6,500 and is never seen above 8,000 feet. Found throughout the State, but most common at the western edge of the plains. Arrives the first week in May and laying begins the first week in June.

685. **Sylvania pusilla.** WILSON'S WARBLER.

Summer resident; abundant. In migration is common or abundant throughout the State, in about equal numbers on the plains and in the mountains. Arrives on the plains about the middle of May and is common for ten days to two weeks. By June 1 has left the plains for the north or gone into the mountains. During the month of June, is moving up the mountains and by the end of June is at its summer home just above timber-line where during July it is the most numerous insect-eating bird. Laying begins the last of June; young are able to fly by the latter part of July. The center of abundance during the breeding season is about 11,000 feet, but it has been known to breed from 6,000 to 12,000 feet. Is very common in the upper parks in August during its fall descent; reaches the lower parks in September; the plains in October and leaves the State late in this month.

685a. **Sylvania pusilla pileolata.** PILEOLATED WARBLER.

Migratory; rare. This is the western form, found regularly from the Great Basin to the Pacific. A specimen taken by

Geo. F. Breninger at Fort Collins May 22, and now in the museum of the Agricultural College is almost typical *pileolata*, much nearer that than *pusilla*. This is the only record for Colorado about which there is no doubt. Several other records probably refer to *pusilla*.

687. **Setophaga ruticilla.** AMERICAN REDSTART.

Summer resident; not uncommon in eastern Colorado; rather rare in western Colorado. In migration on the plains and in the foothills it is fairly common. Arrives about the middle of May. A few breed on the plains and it is not uncommon as a breeder in the mountains below 8,000 feet. Trippe saw a female in July at timber-line, but this is 3,000 feet above its normal range.

697. **Anthus pensilvanicus.** AMERICAN PIPIT.

Summer resident; common. In migration occurs throughout the State; breeds only on the summits of the mountains. Arrives on the plains the last of April and it is about a month later that the last have departed into the mountains. Through May it is in the higher mountain parks and by June has ascended above timber-line to its summer home. Laying begins early in July, as soon as the first grass has started. Most nests are made between 12,000 and 13,000 feet, the lowest known being one on Mount Audubon at 11,000 feet, found with fresh eggs July 3. Never goes below timber-line during the breeding season. In August many wander to the tops of the peaks at 14,000 feet. At this time they gather into flocks and remain high until late in the season. They descend into the upper parks the last of September and some remain above timber-line until October. During October they come back to the plains and leave the State in November.

701. **Cinclus mexicanus.** AMERICAN DIPPER.

Resident; common in suitable localities. Remains near open water all the year. In winter this brings it down to the foothills and larger mountain streams, usually between 6,000 and 9,000 feet, but it has been noted clear down to the plains. Common all winter in the Cañon of the Grand River as far down as Glenwood Springs at about 5,500 feet. Moves back into the mountains as soon as the streams thaw out in April and spends the summer from 8,000 feet to just below timber-line. No record of any nest being found lower than 8,000 feet, but the present writer saw several pairs on the Cache La Poudre the last of July, that, if they nested higher, must have descended very early. Laying begins the last of May and early in June. Remains high in the mountains as late as possible, until it is forced by the coldest weather to descend to the lower valleys.

D. D. Stone records the shooting of one at Hancock, October 16, at 10,000 feet. It was in open water in the ice on a lake. Snow had been on the ground for two weeks and it was snowing at the time. (O. & O. VII. 1882, 181.)

702. **Oroscoptes montanus.** SAGE THRASHER.

Summer resident; not uncommon. Comes east as far as the edge of the plains and is about in equal numbers along the eastern slope of the mountains and in western Colorado. Arrives early in April and breeds from the plains to nearly 10,000 feet. Leaves the State late in October.

703. **Mimus polyglottos.** MOCKINGBIRD.

Summer resident; not uncommon, locally. In southeastern Colorado, along the Arkansas from Pueblo eastward, as abundant as at any place in the south. Fairly common north to Colorado Springs and thence is not common and irregular over the rest of the State east of the mountains. According to Ridgway, C. E. Aiken was the first to record the mockingbird from Colorado (Bul. Essex Inst. V. 1873, 178) but this is an error, since it was found by Maj. Long's party, with nests and young at the Platte River near where Brighton now stands, July 4, 1823. H. G. Smith reports them as quite common in 1895 along Clear Creek near Denver and W. G. Smith says they used to breed on the Big Thompson near Loveland. F. M. Dille says that they used to breed abundantly in Greeley but left for isolated places because their young were so much sought. They breed regularly in the Republican Valley at the eastern end of Arapahoe County. During the summer of 1896, two pairs took up their residence on the grounds of the Agricultural College at Fort Collins where they had never before been seen. Four other pairs were noted in the neighboring foothills to about 6,000 feet. They have several times been seen at Cheyenne and Dr. Jesurn reports the capture of an adult male April 30, 1894, at Douglas, Wyo., 150 miles north of Cheyenne. Arrives in southern Colorado the latter part of April and breeds early in June. Breeds mostly on the plains, but occasionally in the foothills to 8,000 feet.

704. **Galeoscoptes carolinensis.** CATBIRD.

Summer resident; common. Breeds from the plains to about 8,000 feet. Arrives early in May and breeds the latter part of June. Shy, but fairly common on the plains and the eastern slope of the Rocky Mountains; rare in western Colorado. Nowhere in the State is it so common as in most parts of the Mississippi Valley. Returns from the mountains to the plains in August.

705. **Harporhynchus rufus.** BROWN THRASHER.

Summer resident; not uncommon. Almost confined to the plains and only east of the mountains, which it barely penetrates to 7,500 feet. Arrives about the middle of May and breeds throughout its range.

708. **Harporhynchus bendirei.** BENDIRE'S THRASHER.

Summer visitant; accidental. One shot by Brewster at Colorado Springs, May 8, 1882. The first and only record north of Arizona. (B. N. O. C. VIII. 1883, 57.)

715. **Salpinctes obsoletus.** ROCK WREN.

Summer resident; common. More particularly a bird of the foothills and mountains, but extending eastward over all the plains region to Kansas. Breeds on the plains, but more commonly in the mountains from 6,000 to 9,000 feet; much less commonly to 12,000 feet. Arrives on the plains the middle of April and laying begins the latter part of May. At the upper part of its range each of these dates is about a month later. Leaves the mountains in September and the State the latter part of October.

717a. **Catherpes mexicanus conspersus.** CAÑON WREN.

Resident; rare. There are but few records of this species in Colorado. It comes east to the eastern base of the Rocky Mountains and north as far as Boulder where A. W. Anthony saw several November 23, 1892. In the winter it has been noted by C. E. Aiken at Fountain and the present writer saw it the winter of 1895–6 in the Cañon of the Grand River near Glenwood Springs. Rather more common in the mountains of south-central Colorado where, according to W. P. Lowe, it breeds and is occasionally seen as high as 8,000 feet. The only nest recorded to date is the one with five fresh eggs found by H. D. Minot at Manitou June 8, 1880. (B. N. O. C. V. 1880, 223.)

719b. **Thryothorus bewickii leucogaster.** BAIRD'S WREN.

Summer resident; rare. Only four records for Colorado and all on the plains east of the mountains; known however from southern Utah and Arizona and hence will probably yet be found in the lowest portions of western Colorado. Capt. P. M. Thorne shot one at Fort Lyon, April 27, 1886. C. E. Beckham took one at Pueblo, H. G. Hoskins writes that he has seen several near Burlington and W. G. Smith took it at Loveland.

721b. **Troglodytes aëdon aztecus.** WESTERN HOUSE WREN.

Summer resident; common. Occurs in migration over all of Colorado below the pine region and though it breeds through-

out its range, yet in Colorado, it breeds much more commonly in the mountains than on the plains. Arrives on the plains the last of April and in the mountains the middle of May. Breeds from the plains to 10,000 feet. Raises two broods and often three. Laying begins the first of June and continues until late in July. Comes down from the mountains in September and soon after leaves the State.

722. **Troglodytes hiemalis.** WINTER WREN.

Resident; rare. Has been noted but a few times in Colorado. The honor of including it among the breeders of the State belongs to Prof. C. P. Gillette of Fort Collins who found several July 7, 1896, in the mountains thirty miles west of Fort Collins at an altitude of 8,000 feet. They were in company with *aztecus*. Though no nests were found, they were evidently breeding at the time. Later in the same season the present writer saw several birds along the Big Thompson in Estes Park at about 7,000 feet. One was taken in Denver October 13, 1891, by Mr. H. G. Smith. (Nidologist III. 1896–7, 76.)

725a. **Cistothorus palustris paludicola.** TULÉ WREN.

Summer resident; not uncommon, locally. Rather more common in southern Colorado than northern, and more common at the base of the foothills than farther east on the plains. Arrives usually the last of April, but Prof. Wm. Osburn writes that he took two unusually early migrants at Loveland in March, 1889. Laying begins about the middle of June. Breeds on the plains and up to 8,000 feet. Remains in the State until late in September. Mr. A. A. Bennett writes that he has seen them in Routt County in January. There are some hot water swamps, and the Wrens stay in them all winter.

726b. **Certhia familiaris montana.** ROCKY MOUNTAIN CREEPER.

Resident; common. In migration and during the winter occurs on the plains, where typical *montana* has been taken by Capt. P. M. Thorne as far east as Fort Lyon. At the same time it is also found at timber-line where it is resident all the year. The center of abundance during the winter is from 7,000 to 9,000 feet. During the breeding season it is confined to the immediate vicinity of timber-line and is there quite plentiful. Leaves the plains in April and breeds in June.

727. **Sitta carolinensis.** WHITE-BREASTED NUTHATCH.

Resident; not common. The A. O. U. Check List gives the geographical distribution of the typical form as "west to the Rocky Mountains," while *aculeata* is given as coming "east to the plains." Thus the two forms would intermingle in east-

ern Colorado. The only one who has formally noted both forms is V. L. Kellogg, who reports finding both in Estes Park during the summer. (Trans. Kans. Acad. Science, XII. 1889-90, 86.) A specimen taken at Fort Collins is a fair intermediate between the two forms. Not enough material has been collected to define its range in Colorado.

727a. **Sitta carolinensis aculeata.** SLENDER-BILLED NUTHATCH.

Resident; common. This is the common form in Colorado occurring throughout the State from the foothills westward. Winters at the edge of the plains and in the foothills, less commonly nearly to the pines. Breeds occasionally down to the plains, but commonly from about 7,500 feet to timber-line. Its upward movement occurs in April and it breeds the last of May and early in June. Returns to the lower regions in October.

728. **Sitta canadensis.** RED-BREASTED NUTHATCH.

Resident; not uncommon. Migratory on the plains and resident in the mountains to about 8,000 feet, occasionally to 10,000 feet. Less common than the Slender-billed or the Pygmy Nuthatches. Breeds in June.

730. **Sitta pygmæa.** PYGMY NUTHATCH.

Resident; abundant. Comes east only to the edge of the plains and occurs there only in the winter. Descends from the mountains in December and remains through until February. By the first of March all have returned to the mountains. At the same time they are fully as abundant in the mountains, braving the severest cold to at least 8,000 feet. During the summer they are most common from 7,000 to 10,000 feet and a few breed as low as 6,000 feet. The great bulk scarcely make any migration, even vertical. Begins to pair in April and laying begins the latter part of May. Probably two broods are often reared.

733a. **Parus inornatus griseus.** GRAY TITMOUSE.

Resident; not common. Known only from southern Colorado, coming north to El Paso County and east to the eastern foothills. It has been taken from 5,000 to 9,000 feet and is known to breed, but its breeding range is not yet definitely determined. It seems probable that it winters in the foothills and breeds from 5,000 to 8,000 feet.

735a. **Parus atricapillus septentrionalis.** LONG-TAILED CHICKADEE.

Resident; not uncommon. Winters on the plains and in the foothills, occasionally up to 8,000 feet. Breeds in the

mountains from 7,000 to 10,000, rarely above 9,000 feet and rather uncommon breeding on the plains.

738. **Parus gambeli.** MOUNTAIN CHICKADEE.

Resident; abundant. The most common Titmouse in Colorado. Occasionally comes down to the plains in the fall and winters as far east as Pueblo. Resident in the mountains nearly to timber-line. Leaves the lowlands in April and nests from 8,000 feet to timber-line, ranging in the fall to the tops of the loftiest peaks. Breeds early in June.

744. **Psaltriparus plumbeus.** LEAD-COLORED BUSH-TIT.

Resident; not common. Western Colorado, coming east to the eastern foothills, wintering up to 6,500 and breeding from the plains to 7,800. The only records are those of C. E. Aiken and W. P. Lowe.

748. **Regulus satrapa.** GOLDEN-CROWNED KINGLET.

Summer resident; rare, breeding; rather common, in migration. Arrives late in April and is present on the plains but a few days; returning, leaves the last of September. Less common than the Ruby-crown and the few that remain to breed in Colorado, range higher than the bulk of the Ruby-crowns. In migration occurs through the State; breeds only near timber-line at about 11,000 feet. Breeds early in July.

749. **Regulus calendula.** RUBY-CROWNED KINGLET.

Summer resident; abundant, both in migration and breeding. Although very common during the breeding season near the timber-line, but few nests have ever been taken. The first one known to science was taken by J. H. Batty, near Buffalo Mountains June 21, 1873, and contained five young and one egg. During the same year, Henshaw found a nearly finished nest at Fort Garland June 11. W. E. D. Scott took the next nest with five eggs at Twin Lakes June 25, 1879, followed two years later by one with four young, taken by F. M. Drew in San Juan County July 5, 1881. D. D. Stone took a set of eggs in 1883, at Hancock, and saw young August 1, while J. A. Allen saw young on Mount Lincoln the last of July.

Arrives on the plains early in April, passes through the middle mountains during May, and reaches its breeding grounds the last of May and early in June. Only known as a migrant on the plains and in the foothills, the last leaving in the spring migration early in May. Returns to the plains early in October and leaves the State the last of that month. Breeds most commonly from 9,000 feet to timber-line, less commonly 2,000 feet lower. It is rather queer that it should seem to breed at a lower altitude in southern Colorado than in northern. Begins to descend early in September.

751. **Polioptila cærulea.** BLUE-GRAY GNATCATCHER.

Summer resident; rare. Not known north of El Paso County nor west of the mountains. Breeds on the plains and in the foothills to 7,000 feet. H. W. Nash found a nest at Pueblo June 22, containing two young and a cowbird's egg. Lowe notes its arrival at the same place April 27, common May 10.

754. **Myadestes townsendii.** TOWNSEND'S SOLITAIRE.

Resident; common. In the mountains is a permanent resident, winter as well as summer. Only visits the plains during the fall, winter and spring and then not so common as in the mountains and quite local. Leaves the plains about the first of May and returns about the middle of October, but stragglers are found at the base of the foothills, both later and earlier than these dates. Though not common except at the western edge of the plains, Capt. P. M. Thorne took four specimens at Fort Lyon and it is known as a rare fall and winter visitor in western Kansas. Through all the winter it can be found in the mountains from the lower valleys to about 10,000 feet; in summer it breeds from 8,000 to fully 12,000 feet. Pairs the last of April and first of May and laying lasts from the first week in June to the middle of July. Though so abundant and well known, it was not until 1876 that the first nest with eggs was taken. This was by W. L. Lamb in Summit County July, 1876, at 10,000 feet; eggs about ten days incubated. T. M. Trippe found a nest and four eggs at Howardsville July 9, 1880, D. D. Stone found two sets June 20 and one June 25, 1882, at Hancock, and Wm. G. Smith took fresh eggs on Buffalo Creek, Jefferson County, June 18, 1883. During the season of 1883 D. D. Stone took ten sets from June 6 to July 8 at Alpine Tunnel and Hancock. After this they could no longer be called "extremely rare."

756a. **Turdus fuscescens salicicola.** WILLOW THRUSH.

Summer resident; not uncommon. Occurs throughout the lower parts of the State, during migration as far east as Kansas. Breeds in the foothills and parks to about 8,000 feet. Arrives early in May.

758a. **Turdus ustulatus swainsonii.** OLIVE-BACKED THRUSH.

Summer resident, rare; in migration, common. The bulk pass through Colorado on the plains and in the mountains from the first week in May to the last of the month, and on the return arrive in September and leave the State in October. A few remain to breed from the plains to 10,500 feet, but most above 8,000 feet.

759. **Turdus aonalaschkæ.** DWARF HERMIT THRUSH.

Migratory; rare. The exact position of this bird in Colorado is not yet definitely settled. The prevailing form of Hermit Thrush is *auduboni*, but there is a mounted specimen of the typical Dwarf Thrush taken at Fort Collins the first day of October. H. G. Smith at Denver has taken one May 13, 1887, and one September 26, 1884, both identified by Ridgway, and a third that probably should be referred to this form was taken there October 5, 1892. These records make it sure that this form extends regularly during spring and fall migration as far east at least as the western edge of the plains. Concerning those sent to Mr. Ridgway, he says: "Not quite typical, being a little larger than the average, but are much too small for *auduboni* and altogether too gray and too slender-billed for *pallasii*." (Nidologist, III. 1896–7, 76.)

759a. **Turdus aonalaschkæ auduboni.** AUDUBON'S HERMIT THRUSH.

Summer resident; common. Sometimes called the Rocky Mountain Hermit Thrush because it is common and characteristic of that region. The most eastern record is that of Capt. P. M. Thorne and it is fairly common a few miles nearer the foothills during migration. Arrives the last of April and leaves the plains the last of May. Breeds in the mountains from 8,000 feet to timber-line and occasionally to the lower foothills. At the lower altitude in southern Colorado laying begins early in June and is continued on the mountains to the middle of July. Returns to the lower parts in September and leaves the State about the middle of October.

759b. **Turdus aonalaschkæ pallasii.** HERMIT THRUSH.

Migratory; rare. From the east the true Hermit Thrush comes only to the eastern edge of Colorado, thus just touching the range of *audoboni*. Two young-of-the-year were taken September 26, 1885, by Capt. P. M. Thorne at Fort Lyon, and identified for him by Mr. Brewster.

761. **Merula migratoria.** AMERICAN ROBIN.

Summer resident; not common. The robins of Colorado shade from nearly pure *migratoria* on the plains of eastern Colorado to typical *propinqua*. There is no definite dividing line between the two forms, and for two hundred miles east of the Rocky Mountains, birds are often found that are a fair intermediate between the two forms. Birds that can be reasonably assigned to the eastern form occur as far west as the base of the foothills, and V. L. Kellogg mentions taking Robins in Estes Park that were as bright as specimens from eastern Kansas. It

is a fair presumption that the Robins of Colorado as a whole are *propinqua*, and that a few of those on the plains east of the mountains should be referred to *migratoria*. It is not possible to make any distinction between the two forms as regards migration and breeding.

761a. **Merula migratoria propinqua.** WESTERN ROBIN.

Summer resident; abundant. The prevailing form of western Colorado, though specimens have been taken by Capt. P. M. Thorne at Fort Lyon, and it is known as a rare visitant to western Kansas. Much more common in the foothills and on the western edge of the plains than farther east. Arrives from the middle of March to the middle of April, according to the season, and sometimes a few winter in southern Colorado. Nesting begins the first of May and often two broods are reared, the latter early in July. Breeds on the plains and to 11,000 feet. The bulk leave the State late in November. In January, 1897, a few were seen at 8,000 feet among the pines of Boulder County.

765. **Saxicola œnanthe.** WHEATEAR.

Accidental. A European species, straggling to New England and once taken by Minot at Boulder, May 14, 1880. (B. N. O. C. V. 1880, 223.)

766. **Sialia sialis.** BLUEBIRD.

Summer resident; rare. The eastern form comes west to the base of the Rocky Mountains, thence westward its place being taken by *S. m. bairdi.* According to Capt. P. M. Thorne it nested at Fort Lyon the summer of 1886. Beckham took it at Pueblo, Aiken in El Paso County. There are both male and female in the Maxwell Collection, while Mr. Dennis Gale informs the present writer that he has several times taken it at Gold Hill fairly within the foothills of the Rockies. Arrives the last of April.

767a. **Sialia mexicana bairdi.** CHESTNUT-BACKED BLUEBIRD.

Summer resident; not common. Comes east as far as Pueblo, where it occurs in both spring and fall migration. Not uncommon along the base of the foothills and breeds from there up the mountains to 9,500 feet. Arrives the last of March and breeds about the middle of May.

768. **Sialia arctica.** MOUNTAIN BLUEBIRD.

Summer resident; abundant. The most common Bluebird of Colorado, far outnumbering both the other kinds. Common in migration as far east as Fort Lyon and even to Kansas. Arrives in February to the middle of March according to the

season and probably sometimes winters. By the last of March has spread throughout the mountains nearly to timber-line. Breeds on the plains as far east as Pueblo, more commonly at the foothills and abundantly from 7,000 feet to timber-line. Breeds on the plains the last of April and in the mountains during May. Sometimes raises two broods. In autumn wanders upward far above timber-line to at least 13,000 feet. Returns late to the foothills and the bulk leave in November and early December.

ADDENDA.

Some material that has accumulated while this publication was passing through the press necessitates some additions to the foregoing pages.

Page 3. The total species known in Colorado should be 363, of which 230 are breeders.

Page 11. Add *Phalænoptilus nuttalli nitidus* to species that breed on the plains.

Page 12. Add *Empidonax hammondi* to species that breed principally in the mountains.

Page 14. Add *Bubo virginianus arcticus*, *Coccyzus americanus* and *Dryobates pubescens* to the stragglers or doubtful species.

Page 16. SUMMARY.

Change Total species in Colorado to 363
Change Summer residents to 230
Change Breeding on plains, but not in mountains to .. 35
Change Breeding principally in mountains to 21
Change Stragglers to 51

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The State Agricultural College

THE AGRICULTURAL EXPERIMENT STATION

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SHEEP SCAB

A Few Insect Enemies of the Orchard

APPROVED BY THE STATION COUNCIL

ALSTON ELLIS, President

FORT COLLINS, COLORADO

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SHEEP SCAB.

Clarence P. Gillette, M. S.

The diseases known as "scab" in sheep, "itch" in man and "mange" in cattle, horses, dogs and other animals are caused by minute animal parasites that feed upon or just beneath the surface of the skin.

These parasites are spider-like in structure and belong to the true mites, which differ from spiders in being, for the greater part, minute in size, in having but six legs when young, and in having the three parts of the body, head, thorax and abdomen, all united in one. (See figure 1.)

Although the different species of mange mites look very much alike, it is seldom that a species that infests one kind of animal will live upon any other. The species (*Psoroptes communis*) that causes common scab of sheep is known to infest horses and cattle, though it seldom thrives well upon them.

Common scab has long been considered one of the worst maladies that sheep are subject to in this country, and it has also attracted a large amount of attention in Europe and Australia. As the parasites readily spread from sheep to sheep, the disease is properly considered a contagious one and rigid quarantine laws have been enacted nearly everywhere that the disease prevails to prevent, as much as possible, its spread into uninfested localities.

Sheep-feeding has become a very important industry in Colorado during the past few years. Hundreds of thousands of lambs are fattened for the eastern markets during the winter, and nearly all require to be dipped for scab. There is a wide diversity of opinion among feeders as to the best dips to use and as to the best methods of handling the flocks to prevent or cure scab, and it was with a view of settling, or, at least, throwing some light upon these questions, that the experiments and observations reported in the following pages were undertaken. The work has only been in progress during the past winter and spring and is necessarily incomplete. In fact, the present paper should be considered as a progress report rather than a report upon a finished work. I hope, next fall and win-

ter, to make extensive tests of the more promising dips by treating a thousand or more scabby sheep in each.*

SYMPTOMS OF THE DISEASE.

The infection nearly always occurs along the back of the sheep between the base of the neck and the tail. Bad patches sometimes occur well down on the side of the sheep and even upon the tail. The presence of the mites causes uneasiness and, apparently, intense itching, which the animal endeavors to relieve by pulling the wool from the infested spot with its teeth ("digging"), or by rubbing. The first indication is usually a small loose lock of wool projecting from some place upon the side or back of the sheep. If not attended to, the scabby spot increases rapidly in size and the continual pulling entirely removes the wool so that there is soon a bare spot of greater or less extent. Fortunately the mites are gregarious in habit, i. e., living in colonies and not scattering themselves over the sheep generally, so that a thorough treatment of the infested spot will usually result in a permanent cure unless re-infection takes place from some other animal.

When a spot is just starting with, perhaps, a single mite upon it, it can be detected by one who has had a little experience, from the pale or yellowish color of the skin and its moist surface, due to an exudation of serum. The certain test is to actually find the mite or mites present, which is not a difficult matter if one has a fairly good hand lens.

A little later this patch will have increased in size, the central portion will be covered with a yellowish scaly or mealy material somewhat resembling dandruff, produced by the drying of the serum. Finally these spots become thickly covered with scales or "scabs," and the mites mostly migrate into the wool about the margin, where, with their eggs, they often almost cover the skin. I have seldom found mites or eggs under very heavy scab. Sometimes a heavy reddish scab, indicating the presence of blood and an open sore, are found, but such cases are not common in my experience.

HOW THE DISEASE IS SPREAD.

As the disease is caused by a living creature that is able to crawl freely about and to live for several days, either in the egg or mature state, off the body of the sheep, it is easy to understand how the infection may spread from animal to ani-

*The manufacturers of Zenoleum and Skabcura have already offered their dips in any quantity desired for a test, free. This certainly shows the confidence these manufacturers have in their respective dips.

mal. The spreading of the disease is greatly helped by the rubbing and pulling of the wool, which often removes numbers of both mites and eggs.

These mites are never winged and their power of locomotion is not great, so that I do not think it likely that one of these parasites would be able to travel more than a very few rods in its lifetime.

HOW LONG YARDS MAY RETAIN THE INFECTION.

It is important to know how long these mites or their eggs may remain alive in the yards or corrals after the sheep have been removed. My experiments have all been conducted since last November, so they are not as complete as could be desired. I feel very safe in concluding from them, however, that it would be impossible to carry the disease over in the corrals from one year to another, or from fall to spring or spring to fall, and it seems highly improbable that the eggs or mites can be kept alive more than a few weeks under ordinary conditions. In my experiments, a temperature of 0, or 4 or 5 degrees below, have killed both eggs and mites in every case. Eggs kept at a temperature near that of the body will hatch in from four to eight days, and mites kept at the same temperature will seldom live more than five days without food. If kept in a temperature below that at which the eggs will hatch or the mites be active, both will retain vitality for a much longer time, but just how long I have not yet fully determined. For farther information on these points, see tabulated statements and notes.

DESCRIPTIONS OF THE MITES AND THEIR EGGS.

Figure 1 will show the structure of these mites to the average reader better than a technical description. In all stages they are nearly white in color; the females are a little larger than the males, and are about one-fortieth of an inch in length, or almost exactly the size of the dot of this letter (i) when fully grown. The mature insects have four pairs of legs, like the spiders, but the last pair is small, and in the young they are entirely wanting. A very noticeable peculiarity in these mites is the long gossamer threads attached to the third pair of feet, and which trail behind them as they travel along. In a newly-hatched mite I have seen these threads fully two and one-half times the length of the body, and so slender that it required a rather high power of the microscope to see them at their distal ends. The males can be distinguished from the females

by their more rounded form of body, the smaller fourth pair of legs, which do not have the gossamer threads, the two teat-like projections at the extremity of the abdomen, and the large,

Fig.1

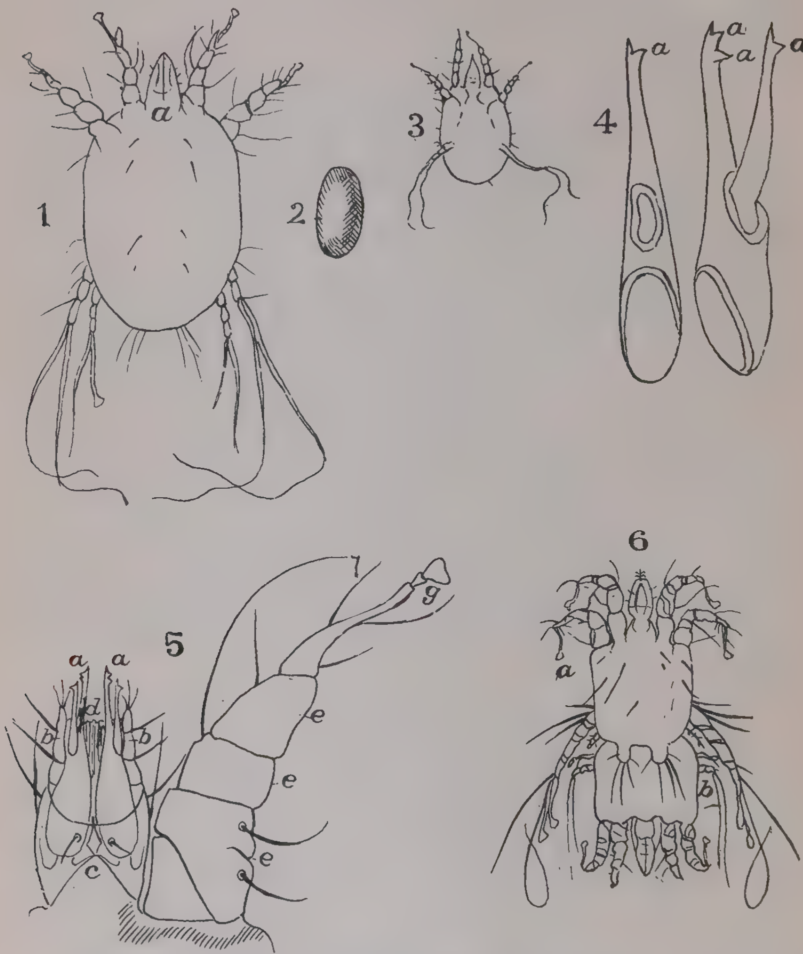

Figure I.—Sheep Scab-Mite (*Psoroptes communis*): 1, adult female, dorsal view; 2, egg; 3, newly hatched young; 4, jaws, which are also shown at 5aa; 5, head and one fore leg, showing mouth parts and sucker-like foot; 6, male above, female below, in copula. (Copied from *Animal Parasites of Sheep*, by Curtice.)

flesh-colored area on the posterior dorsal part of the body. Whenever any considerable number of specimens are taken together there will nearly always be a few pairs in copula, as

shown in Figure I., 6. The eggs are white or whitish-translucent in color, about twice as long as broad and very large as compared with the mites. They are about four-tenths the length of the mature female and eight of them would entirely cover her body. They are deposited upon the surface of the skin of the sheep and not upon the wool. They stick readily to anything that touches them, especially to wool, so they are not readily lost from the sheep if anything should dislodge them from the skin.

EXPERIMENTS FOR THE DESTRUCTION OF THE MITES AND THEIR EGGS—NOTES ON SUBSTANCES USED.

The following substances were all used for the destruction of the mites or their eggs in the laboratory, but only the first ten were applied to sheep.

**The Fort Collins Lime and Sulphur Dip*—I have called this the Fort Collins dip because I know of no name previously given to lime and sulphur dip used in the same proportions. It contains lime, eleven pounds; sulphur, thirty-three pounds to 100 gallons of water. The lime and sulphur are first thoroughly mixed in a small amount of water and boiled for about two hours and then diluted to 100 gallons and used at about 110 degrees temperature. In my experiments the temperature was only about 90 degrees, and the sheep were kept in two minutes.

Dr. Headden, our station chemist, tells me that, if the lime is of good quality, it should take but one pound to cut four pounds of sulphur, and that it is the excess of lime used, or faulty preparation in the lime and sulphur dips that does the injury to the wool that is so often complained of. Mr. Drake tells me that there have been no complaints of injury to the sheep he has dipped in lime and sulphur.

California Dip—Sulphur, 100 pounds; lime, twenty-five pounds; water to make 100 gallons.

The lime and sulphur were first mixed in a small amount of water and boiled about two hours before using.

Also used at one-half the above strength.

Potassium Sulphide Dip—This substance was first suggested by Dr. Headden, who furnished me with a quantity of the crystals as purchased upon the market. These seemed less effectual

*Mr. W. A. Drake, an extensive purchaser and feeder of sheep near Fort Collins, tells me that he has put 38,000 sheep through a dip prepared in this manner the past fall and winter, and in only one instance has fresh scab appeared when the sheep were twice dipped, and he thinks that due to putting a scabby sheep in the bunch after dipping. The sheep were kept in the vat only one-half minute.

than what he afterwards prepared by boiling together sixty pounds of sulphur and nine pounds of washing soda in a small quantity of water, and then diluting this to 200 gallons of the dip. The crystals were used in the proportion of one pound to five gallons of water.

Cooper Dip—This is one of the arsenic-sulphur dips. It is manufactured in England and is one of the leading dips upon the markets. It is sold as a fine yellow powder in paper packages of about ten pounds weight. It mixes readily in either cold or warm water.

Black Leaf Sheep Dip—Manufactured by The Louisville Spirit Cured Tobacco Company, Louisville, Ky. The manufacturers claim this to be a pure and highly concentrated extract of tobacco. It mixes readily in cold or warm water, but the manufacturers recommend that it be used at 110 to 120 degrees. It is a pleasant dip to use in that it requires no stirring during the dipping and does not dry or chap the skin like the lime dips.

Skabcura—Put out by The Skabcura Dip Company, Chicago, Ill. This, like the preceding, is a tobacco dip. A bottle containing enough of the dip for 100 gallons of water is claimed to be the extract from 200 pounds of tobacco stems. It mixes with great readiness in water, cold or hot, and is a pleasant dip to use.

Zenoleum—Manufactured by The Zenner-Raymond Disinfectant Company, Detroit, Mich.

This dip, also the three succeeding ones, seem to be coal-tar dips. They are black, sirupy liquids, mixing without the slightest difficulty in cold or warm water and having a distinct tarry odor. When put in water they all form a white mixture (an emulsion) resembling milk. They are all recommended as disinfectants and washes for sores, and when put upon the skin leave the latter soft and oily with no disagreeable after effect, so that the men using these dips took pleasure in washing their hands in them to make them soft.

Chloro-Naptholeum—Put out by The U. S. Manufacturing Company, Minneapolis, Minn. Seems in all respects like the preceding except that when emulsified with water it does not form quite as white a mixture.

Quibell's Liquid Dip—Manufactured by Quibell Brothers, Newark, England. This dip seems in all respects like the preceding.

Sulpho-Napthol—Manufactured by Sulpho-Napthol Company, Boston, Mass. I have had but a small quantity of this dip to

experiment with, but it seems like the preceding three dips, except that it did not form so complete an emulsion with water, a small amount of black, oily fluid rising to the top.

Australian Dip—Sulphur, 150 pounds; lime, 100 pounds, to 100 gallons of water. The lime and sulphur were mixed with a small amount of water first and heated until all became a bright red liquid and then diluted to 100 gallons.

Copperas Dip—Copperas, thirty pounds; water, 100 gallons.

Flour of Sulphur—The dry powder used pure.

Flour of Sulphur in Water—Used in the proportion of ten pounds of sulphur to 100 gallons of water.

Curtice Dip—Tobacco leaves, fifty pounds; sulphur, ten pounds, to 100 gallons of water. The tobacco was first thoroughly steeped, after which the leaves were removed and the sulphur put in the decoction and boiled for a half hour.

Milk of Lime—Lump lime, 150 pounds; water, 100 gallons. Lime slaked in the water and used at once.

Tobacco Decoction—Tobacco dust, 200 pounds; water, 100 gallons. The tobacco was steeped in the water and then the leaves squeezed and the strong decoction used in full and one-half, one-fourth and one-eighth full strength.

Quibell's Powder Dip—Put out by the same company as Quibell's Liquid Dip. This dip seems almost identical with the Cooper Dip. Like that dip, it is sold in paper packages, and was use in the proportions recommended by the directions. The powder dissolves readily in hot or cold water.

Arsenite of Soda Dip—White arsenic, one ounce; carbonate of soda, one ounce; water, one gallon. The arsenic and carbonate of soda were first put in a small amount of water together, and boiled until the arsenic became entirely dissolved, and then the remainder of the water was added. Also used in weaker solutions.

Carbolic Acid and Corrosive Sublimate—Carbolic acid, eight parts; corrosive sublimate, one part; water, 1,600 parts. (Suggested and prepared by Dr. Headden.)

Carbolic Acid—Pure carbolic acid in water in proportions varying from one part in 100 to one part in 2,000.

Kerosene Emulsion—Soap, one pound; water, one gallon; kerosene, two gallons. After making the emulsion in these proportions in the usual manner the whole was diluted to sixteen gallons. Also used in one-half this strength.

Pure Kerosene—Used without dilution.

Alcohol—Used 95 per cent. pure.

Whale-Oil Soap—Used in the proportion of one pound to two gallons of water.

**Crude Aniline*—Dissolved in water in the proportion of one to 800 by weight.

**Phenyl Hydrazine*—Dissolved in water in the proportion of one to 500 by weight.

MANNER OF APPLYING THE DIPS.

Unless otherwise stated in the notes upon the different dips, it will be understood that all were used at about 95 degrees temperature, and that the time of dipping was two minutes. In the laboratory experiments the mites were in each case procured on the day of the experiment by pulling wool from live scab. The mites were treated by dipping the wool that they were on into the various substances used, and, after two minutes, removing the wool and hanging it on pins to dry. This was thought to come as near the natural conditions as it was possible in the laboratory.

In most cases the dipping was done between five and six in the afternoon, and the first examination made between nine and ten the next morning. Examinations were made under a dissecting microscope, and all mites that could not be induced to move were accounted dead. When possible, a second or even a third examination was made, but the pressure of other work often made this impossible.

It must not be concluded that all dead mites found after treatment are necessarily dead because of the treatment, as an examination of the check lots will show that when removed from the sheep and kept in a warm atmosphere the mites died rapidly after the first few hours when untreated.

LABORATORY EXPERIMENTS.

The final test of any dip must be upon sheep infested with scab. Laboratory tests are of much value to the experimenter in that they can be conducted in larger number under conditions that can be more completely controlled, and they give information that greatly aids in the selection of dips of promise and in the rejection of those that seem worthless. As very little experimental work has been done with sheep dips as yet in this country, and, as it is probable that the subject is to attract con-

*Suggested and prepared by Dr. W. P. Headden.

siderable attention in the future, I have thought it best to record the results of all my experiments with different materials for the destruction of either eggs or mites for the guidance of those who may take up the work hereafter.

EXPERIMENTS WITH THE DIFFERENT DIPS.

Fort Collins Lime and Sulphur Dip—This dip was used upon sheep only; the laboratory tests of lime and sulphur dips were made in other proportions.

On November 18, thirty-five sheep were dipped, care being taken that all were put entirely under at least twice.

Mild cases of scab were known to exist in this bunch, but, unfortunately, the men who did the work misunderstood my directions and put in no sheep having heavy scab, as I intended that they should. December 1 the sheep were dipped again in the same preparation, no sign of scab having developed in the meantime. At this date, April 15, no fresh scab has appeared.

By purchasing the sulphur in a car-load lot, the feeders at this place were able to dip their sheep at less than one cent per head in November.

California Dip—

Laboratory Experiments—Applied October 27. Examined sixteen hours after, when several active, but no dead, mites could be found.

Experiment repeated November 5. Examined sixteen hours after, when four active and seven dead mites were found. Examined forty hours after, when only one living mite could be found.

Repeated again November 6. Sixteen hours after a single mite was found, which was very active. After using this dip the wool would dry into a hard lump, so that it was difficult to find the mites at all. The lump would crush rather easily into a mass of fine powder.

Experiment repeated in one-half the above strength, November 5. Sixteen hours after there were ten dead and five active mites found. Forty hours after there were still five active mites, but only one seemed in good condition.

Experiment on Sheep—One sheep with heavy live scab was treated with this dip November 14.

When examined, November 16, the wool was matted and heavily loaded with a fine powder. The wool was harsh and dry, and could be easily picked from the sheep with the thumb and finger. The wool did not pull from the skin, but would break near the body, where the fibres were nearly eaten off by the lime. No living mites could be found. No living scab has developed to the present time, April 15.

POTASSIUM SULPHIDE DIP.

Table Showing Results of Laboratory Experiments.

Date of Treatment	Condition After 16 Hours		Condition After 48 Hours		Strength Used
	Dead	Alive	Dead	Alive	
**November 1	13	0	----	----	Full Strength
**November 1	3	7	10	0	½ Strength
November 3	3	7	7	3	½ Strength
November 4	8	2	----	----	Full Strength
November 6	22	5	27	0	Full Strength
November 6	0	All	----	----	½ Strength
November 11	Few	0	----	----	Full Strength
November 15	5	5	----	----	Full Strength
November 16	7	2	9	0	Full Strength
November 27	9	16	----	----	Full Strength

The laboratory experiments with this dip were not at all encouraging. Experiments upon sheep did much better.

Only the crystals were used in the laboratory. The "full strength" mentioned in the table was in the proportion of one pound of crystals to five gallons of water.

Experiments on Sheep—The crystals were used in the proportion of one pound to five gallons of water, on November 10, to dip one sheep with a rather large patch of heavy scab on its back. The sheep was dipped but once. The weather being rather cold the sheep was kept in a barn for a few days.

A lock of wool was pulled twenty-four hours after the dipping, on which were found thirty-three mites, and all but one seemed dead. The wool at this time was quite wet.

Forty-eight hours after another lock of wool was examined, on which I found six apparently dead and six active mites. The wool was still moist on the sheep.

The sheep was repeatedly examined at intervals of a few days. The mites soon began to increase rapidly, and by the 1st of December the sheep had a bad case of scab again. On December 12 the sheep was dipped in Zenoleum, one part to 200 of water, and showed no signs of scab afterwards.

Experiment repeated November 18. At this time a bunch of forty sheep was dipped in a preparation made by Dr. Headden as follows:

Nine pounds of potash lye (caustic soda) were dissolved in four gallons of water, and then thirty-two pounds of flour of sulphur were added slowly, while the liquor was kept at boiling heat. After boiling one hour, the whole was put in the dipping vat and diluted to 200 gallons.

**In these two experiments the wool was put in a glass tube before it was perfectly dry and so kept moist the whole time, which probably accounts for the greater effectiveness of the dip in these than in later experiments.

Forty sheep were dipped in this mixture, several of which had heavy scab. After drying, the wool was full of a very fine yellow powder that kept the skin of the sheep completely covered. The sheep were dipped again December 1. No live scab has developed on any of these sheep since the dipping.

I have a letter from Leggett & Brother, New York, offering the lye, or caustic soda, in lots of 1,000 pounds or more at the rate of four cents a pound on board the cars. Calling the sulphur four cents and the lye five cents, after adding freight, and I think these are outside figures on large lots, it would make the dip cost only about eighty cents for 100 gallons. At these figures this dip would rival the lime and sulphur dips for cheapness, and the lye is more easily handled than the lime. It may be difficult to understand why the potassium sulphide crystals did not do as well as the same substance made by using the sulphur and lye, but the former left but little powder in the wool, while the latter left a large amount of it on drying, and I believe the mites are unable to endure, for a very long time, being covered with a dry powder of any sort. It will not do to rest the value of this dip upon a single experiment, but it seems to me to give promise of being a very cheap and practical dip. I hope to be able to test it farther at another time.

It will be noticed that all the lime and sulphur dips did better on the sheep than in the laboratory experiments. I believe it to be due to the continuous action, on the mites, of the fine dust that remains so long in the wool after dipping. There is some reason to think that the action of these dips is largely to drive the mites from the sheep and cause them thus to perish.

LABORATORY EXPERIMENTS WITH COOPER DIP.

Date of Treatment	Condition after 16 Hours		Condition after 40 hours	
	Dead	Alive	Dead	Alive
*October 31	----	----	10	12
November 3	----	----	16	1
November 4	13	1	14	0
November 5	5	1	6	0
November 9	----	----	10	3
November 11	10	4	----	----
November 27	----	----	10	3
Totals	28	6	56	16

One lock was dipped on November 5 at one-half the ordinary strength. and at the end of forty hours there were ten dead and five living mites.

*This lock of wool was dried on paper after dipping, which took the water out much more quickly than if dried like the others. This probably accounts for the lessened effect of the dip.

Experiments on Sheep—On November 10, one sheep, with moderately heavy live scab on the back, was treated with the Cooper Dip—one pound to ten gallons of water.

The sheep was kept in the barn for a few days. Twenty-four hours after dipping the wool was still very wet. A lock was pulled and examined that contained forty-seven dead and nine living mites.

At the end of forty-eight hours the wool was still moist. An examination showed a good number of dead and one living mite in the wool.

On November 13 the sheep was examined again, and an occasional living mite was found. By far the greater number were dead. The living mites were fully grown, and could not have come from eggs since dipping. The sheep was examined November 16, and again December 5, and a few living mites found on both occasions. On December 12 it was dipped again as before. The sheep has shown no scab since.

November 18, a bunch of forty sheep was treated with Cooper Dip, and the treatment was repeated December 1. In this bunch there were but three known cases of scab, and two of these were rather light. One sheep had a rather heavy, but not large, patch of scab on the rump. No farther signs of scab were noticed until January 7, when the sheep that had the somewhat heavy scab on the rump was seen "digging," and an examination showed a small spot of fresh scab near the old one. This sheep was "patched," and there have been no signs of scab in this bunch since.

This dip has been largely used in this vicinity for some years, and is considered by many feeders as a good dip, but most of the men who have used it tell me that unless there is very slight signs of scab among their sheep they have to dip twice, and if the sheep are very scabby they nearly always have to do some "patching" after twice dipping. The expense of the dip is about twice that of the lime and sulphur.

BLACK LEAF DIP.

Table Showing Results of Laboratory Experiments.

Date of Treatment	Condition after 16 hours		Condition after 48 hours		Condition after 4 days		Strength Used
	Dead	Alive	Dead	Alive	Dead	Alive	
November 2	6	1	----	----	----	----	
November 3	10	3	13	0	----	----	
November 6	3	6	6	3	6	3	$\frac{1}{40}$
November 27	9	9	----	----	----	----	
December 12	12	3	----	----	----	----	
November 5	5	6	9	2	----	----	$\frac{1}{50}$
November 6	0	18	4	14	Few	Several	$\frac{1}{80}$
November 5	6	13	14	5	----	----	$\frac{1}{100}$

Experiments on Sheep—One sheep with a patch of moderately heavy scab, the size of a man's hand, was dipped with Black Leaf Dip, in the proportions of one to forty by measure, on November 10.

The sheep was examined twenty-four hours after, and several mites seen crawling about in the wool. The wool was still quite wet. Two days after the application a lock of wool was pulled, upon which ten living and about an equal number of dead mites were found. The living mites seemed rather sluggish.

November 13, the sheep was examined and only an occasional living mite could be found. Those found were too large to have hatched from eggs since dipping. On November 16, a careful search revealed but two mites, and on the 19th I looked in vain to find a living mite. The sheep was also carefully examined on December 5 and again on the 19th, without my finding mites or living scab.

On February 6 the sheep was noticed rubbing its tail against a feeding trough, and on examination it was found that there was a bad patch of scab covering most of the dorsal surface of that organ and two small spots were starting on the rump at the roots of the tail. The mites that survived the effect of the dip seem to have migrated to the tail and were there overlooked in previous examinations.

Experiment Repeated on a Larger Scale—On November 18, three bunches of sheep of forty each were treated with Black Leaf Dip in the proportion of one gallon to forty-two gallons of water. These bunches were treated again December 1. There

were a few cases, only, of rather mild scab among these sheep. On the second day after dipping, one sheep was found with a few living but apparently sick mites. Since that time no scab has developed in any of the pens containing these sheep.

Three sheep known to have some scab when first dipped were kept out at the second dipping, and one of these on January 8 was found to have a small spot of live scab near the old patch of moderately heavy scab. The other two cases, which were rather mild, were entirely cured by the one treatment.

All my experiments seem to indicate that this dip kills slowly but quite surely. Moderately bad cases were in some instances entirely cured by once dipping, while others broke out again. The dip is a pleasant one to use but is rather expensive. I hope to test it further.

SKABCURA DIP.

Laboratory Experiments—November 3, mites were dipped in this preparation in twice the recommended strength.

Sixteen hours after, seven mites were active and about an equal number (not counted) seemed dead. At the end of forty-eight hours only four mites remained active.

Another lot was dipped on the same date in the recommended strength of this dip. Sixteen hours after, all seemed perfectly active. After fifty-six hours many were still active. No count was made.

This dip seemed much more effectual when applied to sheep.

Experiment on Sheep—On November 10, one sheep with moderately heavy scab was dipped with this preparation.

A lock pulled from the sheep twenty-four hours after, gave four dead and ten active mites.

Another lock, taken forty-eight hours after treatment, gave ten apparently dead and nineteen active mites. On November 13 only a very few living mites could be found on this sheep, and on the 16th of the same month I was unable to find any, and none have appeared since.

My early laboratory experiments with this dip were so unpromising that I dropped it to take up dips of more promise, but in following through the effects of the dip on the one sheep treated, it seems that the effect of Skabcura is much like that of Black Leaf, namely, having a cumulative effect, extending over a number of days. This dip seems to me to promise well.

ZENOLEUM.

Laboratory Experiments—My first experiments with this dip were in the proportion of one part to twenty-five and one part to fifty of water. All were killed that were thus treated.

Table Showing Results of Laboratory Experiments.

Date of Treatment	Condition after 16 Hours		Strength Used
	Dead	Alive	
November 4	6	0	$\frac{1}{100}$
November 5	18	0	
November 6	12	0	
November 6	13	0	$\frac{1}{200}$
November 9	10	0	
November 11	8	0	
December 2	13	0	
December 5	14	0	
December 26	10	0	
February 6	30	0	
February 6	20	0	
November 9	9	0	$\frac{1}{400}$
November 11	16	0	
November 12	19	0	
November 13	6	0	
December 12	14	1	
February 6	43	1	
February 6	27	1	
November 11	20	0	$\frac{1}{800}$
November 12	36	11	
November 13	12	10	
December 12	10	10	
November 11	2	7	$\frac{1}{1600}$
November 12	0	8	
November 12	0	Many	$\frac{1}{3200}$

The experiments with this dip gave such promising results from the start that I was led to test it more thoroughly than any other, both in the laboratory and upon sheep.

Experiments on Sheep—One sheep with very heavy scab covering a space about six inches wide and twelve inches long on the shoulders and back was dipped with Zenoleum, diluted 100 times with water, on November 10.

The sheep was examined the next day and many times thereafter, but no live scab appeared again and no living mites have since been found. The scab healed quickly and the sheep has done well ever since.

On the same date another sheep with heavy live scab was dipped in Zenoleum diluted 200 times. Twenty-four hours after dipping, wool was pulled showing many dead mites but no living ones. The sheep has been frequently examined since, but no live scab has appeared during the six months.

On December 12, one sheep not cured by previous dipping with potassium sulphide, was dipped in Zenoleum diluted 200 times, and has shown no live scab since.

On the same date, two sheep, one with a small patch of light scab, and one with a small patch of rather heavy scab, were dipped in Zenoleum diluted 600 times. In both cases the scab seems to have been completely cured, no signs of live scab appearing since.

A Bunch of Sheep Dipped Once—On November 18 a bunch of forty sheep, many of them with heavy live scab, was dipped in Zenoleum diluted 200 times. No scab was afterwards found in this bunch until February 9, at which time six cases of live scab were found, all but one very light. It was found that the one sheep with heavy scab was put in the bunch on December 13 in order to make this bunch of sheep compare in numbers with other bunches that were to be used in a feeding experiment. The scab had gone unnoticed, as it had developed in a large patch of short wool that could not be pulled by the sheep. It seems to me that the presence of this one sheep would readily account for the five incipient cases. However this may be, there were several bad cases that never showed any scab after the dipping.

A Bunch of Sheep Dipped Twice in Zenoleum, Diluted 200 Times—Another bunch of forty sheep that was dipped in Zenoleum, one to 200, on November 18, was dipped again on December 1. This bunch, like the preceding, had a good number of cases of heavy scab.

No live scab was found in this pen until February 9, when the sheep were all examined and one was found with a small patch of fresh scab about one inch in diameter. On December 13, three sheep were put in this pen also, preparatory to a feeding experiment, and on the date that the scabby sheep above mentioned was found, these three sheep were also found to have some scab; one of them had a bad patch on its tail, which it was seen rubbing on a feeding trough. The three sheep were

"spotted" and no scab has since appeared. It seems probable that the sheep put into the pen were the cause of the one sheep that had been dipped with Zenoleum getting scab again.

A Bunch of Sheep Dipped Twice in Zenoleum, Diluted 400 Times—On November 18, and again December 1, a bunch of forty sheep was dipped in Zenoleum diluted 400 times. No live scab appeared again until March 2, when one sheep with a small patch, less that an inch in diameter, was found. It is the only case that has appeared. This bunch had a good number of very scabby sheep when dipped.

EXPERIMENTS WITH CHLORO-NAPTHOLEUM.

Table Showing Results of Laboratory Experiments.

Date of Treatment.	Condition after 16 Hours		Condition after 44 Hours		Strength Used
	Dead	Alive	Dead	Alive	
November 14	All	0	----	----	$\frac{1}{10}$
November 26	30	0	----	----	
November 14	Many	2	----	----	$\frac{1}{200}$
November 16	14	0	----	----	
November 14	8	8	----	----	$\frac{1}{400}$
November 16	15	3	----	----	
November 14	0	All	----	----	$\frac{1}{800}$
November 16	----	----	3	4	

Applied to Sheep—On November 18, this dip was applied to forty sheep in the proportion recommended on the cans, which is three quarts in 200 gallons of water. There were a few cases of mild scab in this bunch, but no heavy scab. The treatment was not repeated and no scab has appeared since dipping. Further experiments are necessary before drawing definite conclusions regarding this dip.

EXPERIMENTS WITH QUIBELL'S LIQUID DIP.

Table Showing Results of Laboratory Experiments.

Date of Treatment	Condition after 16 Hours		Strength Used
	Dead	Alive	
February 26	14	0	$\frac{1}{100}$
January 5	10	0	$\frac{1}{200}$
February 26	19	0	$\frac{1}{200}$
February 27	16	0	$\frac{1}{200}$
January 12	12	0	$\frac{1}{200}$
January 5	14	0	$\frac{1}{400}$
January 12	9	3	$\frac{1}{400}$
February 26	27	0	$\frac{1}{400}$
February 27	15	1	$\frac{1}{400}$
January 12	8	0	$\frac{1}{800}$
February 27	14	0	$\frac{1}{800}$

Experiments on Sheep—On December 12 six sheep were treated with this dip as follows: Two sheep in a mixture of one part of dip to 200 parts of water; two sheep in a mixture of one part of dip to 400 parts of water; two sheep in a mixture of one part of dip to 600 parts of water. One of the sheep, dipped in the strongest preparation, had a large patch of heavy scab along the back, while the other had only a very small patch of light scab. In each of the weaker mixtures one sheep was dipped having a small but moderately heavy live scab, and one having one or two patches of very light scab. The sheep with heavy scab, dipped in the strongest mixture, was not cured, the mites continuing both on and about the old scabby spot. The one having very light scab was cured.

The two sheep dipped in the one to 200 strength were both cured.

The sheep with the heavier scab, dipped in the one to 600 strength, was not cured, while the one with incipient scab has shown no signs of scab since dipping.

LABORATORY EXPERIMENTS ONLY.

SULPHO-NAPTHOLEUM.

This dip was not obtained in time to enable me to do much with it. A lock of wool containing thirty-seven mites was dipped in this substance, diluted 200 times, and at the end of sixteen hours all were dead. Another application in one-half the above strength, in which forty-two mites were used, resulted in the death of all within the sixteen hours.

QUIBELL'S DRY DIP.

Three different lots of mites on wool were dipped in the proportions recommended on the packages. Sixty-six mites were included in the experiments, about one-third of which were alive at the end of sixteen hours. In one case the mites were examined after sixty-four hours and several found active. The indications are that this will not prove a very effectual dip.

CARBOLIC ACID.

One part to 100 parts of water. One lot of six mites were all dead after sixteen hours. One lot of fourteen mites gave nine dead and five living after twelve hours.

One part to 200 of water. A lot of fifteen mites treated in this strength all seemed dead at the end of sixteen hours. Another lot of a good number, but not counted, were about half dead at the end of twelve hours.

One part to 400 parts of water. One lot treated, and about half were active at the end of sixteen hours. Also used in proportions of 1 to 500, 1 to 1,000 and 1 to 2,000, but in no case did the treatment seem to kill any mites inside of sixteen hours. As carbolic acid is a dangerous substance to put animals into, it seems as though it is very doubtful if it can be employed safely in sufficient strength to kill the mites.

ARSENITE OF SODA.

Table Showing Results of Laboratory Experiments.

Date of Treatment	Condition After 16 Hours		Condition After 44 Hours		Strength Used
	Dead	Alive	Dead	Alive	
November 5	12	0	----	----	Full Strength
November 6	10	4	7	7	½ Full Strength
November 11	10	0	----	----	⅔ Full Strength
November 11	12	0	----	----	⅓ Full Strength
November 12	3	3	4	2	⅓ Full Strength
November 13	16	9	----	Few	⅓ Full Strength
December 6	10	6	10	6	¼ Full Strength
December 6	6	10	4	12	⅛ Full Strength

Full strength, as given in the above table, would be one ounce of arsenic and the same of carbonate of soda to one gallon of water. The experiments would indicate that, if used much weaker than this, it would not be very effectual. I believe this dip too poisonous to be used with safety.

AUSTRALIAN DIP.

Laboratory experiments with this dip were not satisfactory, as the solution on drying became a hard lump that inclosed the mites. On crushing this it became a mass of dry powder. Most of the mites that could be found after sixteen hours were dead, but in nearly every case a few living were found also.

There is no doubt but what this would be a very effectual lime and sulphur dip, but I believe it too strong to use on the sheep, and stronger than is necessary to kill scab.

COPPERAS DIP (GREEN VITRIOL).

Two tests were made in the laboratory of copperas as a dip. In one, the proportions were three pounds of the crystals to ten gallons of water, and in the other three pounds of the crystals to twenty gallons of water. In the former strength, about one-third of the mites were quiet at the end of sixteen hours, and in the latter strength only one mite in eight seemed dead at the end of the same time. At the end of forty-four hours one-half of those treated with the weaker solution were still active.

FLOUR OF SULPHUR (DRY).

Dry sulphur was thoroughly dusted into a lock of wool containing scab mites. At the end of sixteen hours four dead and five living mites were found, the latter having all left the wool. At the end of forty hours two mites were still crawling about covered with sulphur.

FLOUR OF SULPHUR IN WATER,

Used in the proportion of one pound to eight gallons, and one pound to twelve gallons of water. In the former case there were four dead and five active ones at the end of sixteen hours. At the end of forty hours one mite covered with sulphur was still active. In the weaker strength all the mites were active at the end of twelve hours.

CURTICE DIP.

Only one laboratory test was made with this dip. After sixteen hours there were many active and few, if any, dead mites. At the end of five days two active mites were found.

A very similar dip, prepared in the proportions of four pounds of strong tobacco and one pound of sulphur to ten gallons of water, was also used. At the end of sixteen hours the mites seemed uninjured. Only one test.

MILK OF LIME.

Wool treated with this dip became a hard lump on drying. After crushing the lump, at the end of sixteen hours, three living mites were found. Probably there were dead ones present, but, being quiet, were not seen. It would seem that lime has but little effect on the mites.

TOBACCO DECOCTION.

The first lot dipped was kept under for only one minute, and then the wool was dried by laying it on blotting paper. Nearly all the mites were lively at the end of four days. The decoction was also used in one-half, one-fourth and one-eighth the above strength in the same manner, and with the same result in each case.

Very strong tobacco leaves, from tobacco raised by the horticultural department, were also used in the same proportion (two pounds to a gallon of water), but the dipping was for two minutes, and the drying of the wool was in the usual manner. At the end of forty-four hours twelve dead and eight active mites were found.

These experiments seemed so unfavorable for tobacco that I concluded not to experiment with it farther. It is very possible that tobacco has a cumulative effect not shown in these experiments.

CARBOLIC ACID AND CORROSIVE SUBLIMATE.

Only one lot treated. At the end of twenty-four hours there were twelve active mites and few, if any, that were dead.

KEROSENE EMULSION.

Having found kerosene emulsion very effectual in destroying lice that infest cattle and hogs, I expected it would be an effectual remedy for scab in sheep. My laboratory experiments were so disappointing that I did not test the emulsion farther. It might have proven more effectual on sheep.

The mites were first dipped for one-half minute in full and one-half strengths. At the end of sixteen hours the mites were all lively, though wet with kerosene. The experiment was repeated in both of the above strengths, and at the end of forty-four hours all the mites were lively.

KEROSENE.

Failing with kerosene emulsion, I made one test with pure kerosene to see if it would kill. A lock of wool containing mites was dipped for one minute. At the end of two hours all the mites were active. At the end of sixteen hours four semed dead and five were still active. All were wet with the oil. At the end of forty-eight hours all were dead. Kerosene, either pure or in the form of an emulsion, may be a sure destroyer of the mites, but it is certainly not rapid in its action.

ALCOHOL.

Finding that kerosene had so little effect, I thought I would see what 95 per cent. alcohol would do. A quantity of mites was dipped for one minute in this substance. At the end of sixteen hours all were still active, and at the end of forty-eight hours only a few had died.

WHALE-OIL SOAP.

Used in the proportions of one pound to two gallons of water, and in one-half and one-fourth of this strength, and with no apparent effect in any case. In the strongest preparation many mites were alive at the end of sixty-four hours.

EXPERIMENTS WITH THE EGGS.

There is a prevailing opinion that the eggs are not killed by the applications that destroy the mites, and that, as a consequence, a second dipping is made necessary to destroy the young mites hatching from the eggs that survived the first treatment. It is commonly recommended to dip a second time from ten to fourteen days after the first treatment, but I can not find that anyone has actually determined the time required for the eggs to hatch. There is also the greatest difference of opinion as to the length of time the eggs may survive when off the sheep, some thinking they may live for years, and others that they can not survive more than a few weeks. These are all matters of very great importance, and the experiments tabulated below were conducted for the purpose of throwing light upon them. The eggs are difficult to obtain in sufficient numbers for experimental purposes, and it is not a very easy matter to keep them under a very close approach to natural conditions. The method that I adopted was to use small glass tubes supplied with corks. The cork, in each case, was removed, moistened with saliva on the inner end, the eggs for the particular experiment placed upon it, where they adhered without trouble after the cork was replaced. The tubes were then carried in an inside vest pocket during the day and kept in a warm place during the night. Any ordinary low temperature seemed to have no effect upon the eggs except to lengthen the period of incubation.

Tabulated Experiments with Eggs of Sheep Scab-Mite.

Date of Application	Date of Notes	Number of Eggs		Treated With	Strength of Dip
		Hatched	Unhatched		
Nov. 27	Dec. 11	0	9	Black Leaf	1 to 40
Nov. 7	Nov. 12	10	0	Black Leaf	1 to 42
Nov. 19	Nov. 27	1	0	Black Leaf	1 to 50
Nov. 17	Nov. 26	2	7	Phenyl Hydrazine	Full strength
Nov. 17	Dec. 9	0	7	Crude Aniline	Full strength
Nov. 17	Dec. 9	0	2	Crude Aniline	One-half strength
Nov. 7	Dec. 9	0	2	Zenoleum Dip	1 to 100
Nov. 27	Dec. 11	0	5	Zenoleum Dip	1 to 200
Dec. 13	Dec. 24	0	1	Zenoleum Dip	1 to 200
Feb. 7	Feb. 24	0	4	Zenoleum Dip	1 to 200
Feb. 7	Feb. 27	0	12	Zenoleum Dip	1 to 200
Nov. 13	Nov. 26	0	6	Zenoleum Dip	1 to 400

Date of Application	Date of Notes	Number of Eggs		Treated With	Strength of Dip
		Hatched	Unhatched		
Nov. 20	Nov. 26	0	13	Zenoleum Dip	1 to 400
Nov. 20	Dec. 9	0	13	Zenoleum Dip	1 to 400
Dec. 13	Dec. 24	2	4	Zenoleum Dip	1 to 400
Feb. 7	Feb. 27	0	12	Zenoleum Dip	1 to 400
Feb. 7	Feb. 24	0	7	Zenoleum Dip	1 to 400
Nov. 13	Nov. 14	1	0	Zenoleum Dip	1 to 800
Nov. 13	Nov. 17	3	0	Zenoleum Dip	1 to 800
Feb. 7	Feb. 27	0	10	Sulpho-Naptholeum	1 to 200
Feb. 10	Feb. 24	0	9	Sulpho-Naptholeum	1 to 200
Nov. 20	Dec. 10	0	1	Cooper Dip	
Nov. 27	Dec. 11	0	5	Chloro-Naptholeum	1 to 100
Nov. 17	Dec. 1	0	4	Chloro-Naptholeum	1 to 200
Nov. 17	Dec. 1	0	8	Chloro-Naptholeum	1 to 400
Nov. 27	Dec. 1	0	6	Quibell's Liquid Dip	1 to 100
Nov. 27	Dec. 14	2	5	Quibell's Liquid Dip	1 to 200
Nov. 28	Dec. 14	0	9	Quibell's Liquid Dip	1 to 200
Dec. 13	Dec. 24	0	13	Quibell's Liquid Dip	1 to 200
Nov. 27	Dec. 14	0	4	Quibell's Liquid Dip	1 to 400
Nov. 28	Dec. 14	0	14	Quibell's Liquid Dip	1 to 400
Dec. 13	Dec. 24	0	4	Quibell's Liquid Dip	1 to 400
Nov. 27	Dec. 11	1	10	Quibell's Liquid Dip	1 to 800
Nov. 6	Nov. 12	1	0	Potassium Sulphide Dip	1 pound to 5 gallons
Nov. 27	Dec. 11	0	4	Potassium Sulphide Dip	1 pound to 5 gallons
Nov. 7	Nov. 12	1	0	Arsenite of Soda	1 ounce to 1 gallon
Nov. 13	Nov. 19	2	0	Arsenite of Soda	1 ounce to 4 gallons
Nov. 27	Dec. 11	1	19	Quibell's Dry Dip	According to direct'ns
Nov. 27	Dec. 9	0	5	Quibell's Dry Dip	According to direct'ns
					Minimum Temperatures
*Nov. 19	Dec. 30	2	1	Out of Doors	8.3°
Nov. 27	Dec. 14	0	6	Out of Doors	-9.8°
Nov. 23	Dec. 9	0	6	Out of Doors	5.1°
Nov. 19	Dec. 24	0	5	Out of Doors	3.2°
Nov. 30	Dec. 11	0	1	Out of Doors	1.5°
Feb. 6	Mar. 13	0	2	Out of Doors	-5.3°
Feb. 6	Feb. 24	5	8	Out of Doors	11.8°
Feb. 9	Mar. 13	0	7	Out of Doors	-5.3°
Feb. 9	Mar. 7	0	2	Out of Doors	$.1^\circ$
Feb. 11	Feb. 24	0	4	Out of Doors	11.8°
Feb. 20	Feb. 27	0	25	Out of Doors	$.1^\circ$

An examination of the preceding table will show that the eggs are nearly, if not quite as easily killed, as the mites. It is possible that the eggs are more protected by the scabs than the mites, but in all the above experiments mites and eggs were treated alike on the wool and seem to have been killed about equally well.

It seems strange that in the use of Black Leaf all of the eggs should have hatched that were taken from a sheep twenty-four hours after dipping, and nearly all should have been killed that were treated in the laboratory.

* This lot was kept on an outer window sill.

The tar dips all did splendidly in destroying eggs. Zenoleum was most used. In dilutions of one to 100 and one to 200 it killed all. When diluted 400 times, only two hatched out of fifty-seven. In the proportion of one to 800, all hatched.

Out of a total of sixty-eight eggs treated with Quibell's Liquid Dip, only three hatched. Smaller numbers were dipped in Chloro-Naptholeum and Sulpho-Napthol and none hatched.

Effects of Exposure on Hatching the Eggs—The effects of exposure on the hatching of the eggs may be summarized as follows:

Four eggs were out five days with the minimum temperatures ranging between 11.8 degrees and 24.8 degrees. None hatched.

Thirteen eggs were out three days when the minimum temperatures ranged between 11.8 degrees and 24.5 degrees. Five hatched.

Twenty-five eggs were out fourteen days, when the minimum temperature ranged between .1 degree and 34 degrees. None hatched.

Six eggs were out twenty-one days when the minimum temperatures ranged between 12 degrees and 37 degrees. None hatched.

Two eggs were out thirty-two days when the minimum temperatures ranged between —5 degrees and 34 degrees. None hatched.

Seven eggs were out thirty-five days when the minimum temperatures ranged between —5 degrees and 34 degrees. None hatched.

Six eggs were out one night when the temperature went down to —9.8 degrees. None hatched.

One egg out one night when the temperature went down to 15 degrees. Did not hatch.

Five eggs were out eight nights when the temperature went to a minimum of —11.8 degrees. None hatched.

Three eggs were out a few nights (dates lost) when the temperature went to a minimum of 8.3 degrees. Two hatched.

Four eggs were out a few nights (dates lost) when the minimum temperature went down to —5.3 degrees. None hatched.

Do not understand that any of the eggs hatched while exposed to the cold. As soon as brought in the eggs were carried in a warm pocket, as before described.

These experiments show that the eggs may be subjected to a temperature of 8.3 degrees and still hatch. Those subjected

to a temperature of 5 degrees or lower did not hatch in any case. It seems probable that the eggs will not bear a temperature as low as 0 and live.

Whether or not exposure will kill one of these eggs probably depends upon, at least, three things, viz., the degree of cold, the duration of the exposure and the stage of incubation of the egg when exposed.

Period of Incubation—When carried in the pocket, the longest time that eggs have lived and hatched after being removed from a sheep has been nine days. One egg known to have been laid November 3, was kept in a warm pocket and the mite emerged on November 8. Time of incubation evidently depends much on temperature. In their natural position on the skin of the sheep and protected from the cold by a heavy coat of wool, it is probable that the eggs hatch in from three to five days.

Where the Eggs are Placed—The eggs of these mites are not glued to the fibers of the wool, neither are they inserted beneath the surface of the skin, but are placed directly upon the moist skin or upon light scab.

EFFECT OF EXPOSURE ON THE MITES.

It is also a matter of much importance to know how long the mites can live off the sheep. How soon after scabby sheep have been turned out of a corral or field will it be safe to put healthy sheep in them without danger of their becoming diseased? The following experiments bear upon this point, but it must be remembered that I have been able to study the conditions during cold weather only.

EXPERIMENTS IN WHICH THE MITES WERE KEPT WARM.

In these experiments the mites were placed on wool in small vials and carried in an inside pocket during the day and were kept at a temperature of about 60 degrees during the night.

Lot 1—Fourteen mites of different ages, taken November 3.

November 4, all seemed active; November 5, five were active and nine quiet; November 6, only two were active; November 7, there were no signs of life.

Lot 2—Thirty-six mites of all ages, taken October 31.

November 2, eighteen seemed dead and eighteen were active; not examined again.

Lot 3—Fifteen mites taken November 5.

November 6, seven appeared dead and eight alive; November 7, only two showed any signs of life.

Lot 4—Seventeen mites taken November 6.

November 7, two seemed dead and the remainder alive; November 9, a few were still active, no count made; November 11, all were dead.

Lot 5—Eighteen mites taken November 12.

November 13, only fourteen were active; November 14, only four were active; not examined again.

Lot 6—Thirteen females taken November 13.

November 19, all were dead and no eggs had been laid.

Lot 7—A large number (not counted) of mites taken November 19.

November 27, one very sluggish mite was all that showed any signs of life; November 28, all were dead.

Lot 8—A large number of mites taken November 27.

Not examined till December 2, when all were dead.

The longest time that a mite lived in any of the above experiments was eight days. As a rule, all were dead at the end of five days.

EXPERIMENTS IN WHICH MITES WERE KEPT OUT OF DOORS.

In these experiments, mites were exposed for a greater or less time on wool, in vials, out of doors, then they were brought in and warmed to see if they would become active. If the mites were still alive they always became active in a very few minutes when the vials were warmed in the hand or with the breath.

Lot 1—A quantity of mites taken and put out November 3.

November 5 and 6, all seemed lively on warming; on the 6th, 7th and 8th, a few of the mites failed to revive, but no counts were made; on the 9th, only four seemed alive; on the 10th, only three, and on the 12th, two; on the 14th, two, and on the 17th, none. So that two mites in this case lived at least eleven days. Minimum temperature during the time was 13 degrees.

Lot 2—A good number of mites put out along with the preceding.

Examined for first time November 23, when all the mites became active on being warmed. Minimum temperature during the time, 13 degrees.

Lot 3—A quantity of mites put out November 19.

Examined for the first time November 28, when all were found to be dead. Minimum temperature while out, —11.3 degrees.

Lot 4—A large number of mites put out November 27.

Examined November 28, when all were dead. Minimum temperature during the night, —9.8 degrees.

Lot 5—Like the preceding, except that they were kept on an outer window sill where, according to tests made later, the temperature was probably about 7 degrees higher than upon the ground, or —2.8 degrees.

November 28, all the mites were dead.

Lot 6—Ten mites put out January 29.

February 1, on warming the mites, six, none of which were adults, became active; four, all adults, did not revive. Those that did revive seemed very sluggish. The minimum temperatures for the three nights were 10.7 degrees, 7.8 degrees and 8 degrees respectively.

Lot 7—A number of mites put out November 23.

When first examined, January 3, all were dead. Minimum temperature during this time, 11.3 degrees.

Lot 8—Mites put out November 30.

Examined January 3, when all were dead. Minimum temperature for this time, 5 degrees.

Lot 9—Mites put out February 6.

Examined February 9, when all became active on warming. They were kept in but a few minutes and then put back. The minimum temperature to which these mites was subjected was 11.8 degrees.

Examined again March 9, when all were dead. Minimum temperature during this time, 5.3 degrees.

Lots 10 and *11*—Put out February 6 and February 9, respectively.

Both lots were examined for the first time March 24, when all the mites were found dead. The minimum temperature during the exposure was 5.3 degrees.

Lot 12—Put out February 23.

Taken in and warmed February 24, when all became active. The lowest temperature during the night, 5 degrees.

Lot 13—Mites put out February 6.

First examined March 9, when all were found to be dead. Minimum temperature during this time, — 5.3 degrees.

The conclusions that may be drawn from the foregoing experiments are the following:

First—That the mites can not endure a temperature much below zero and survive, even for a single day.

Second—That the mites can endure a temperature of 5 degrees and live.

Third—That the immature mites can endure as low, if not a lower, temperature than the adults.

Fourth—That the mites may live very much longer in a temperature low enough to keep them dormant than in a warm

temperature that will keep them active, provided the temperature is not low enough to kill them and that they are not supplied with food.

Fifth—That they will live longer in a moderately low temperature if the temperature is kept steadily below that point which will make them active. In other words, a steady low temperature is not as destructive to them as alternating low and high temperatures.

The longest that mites were kept alive with above experiments was twenty days.

The results with the preceding experiments, both with eggs and mites exposed to out-door temperatures, make it almost certain that the infection can not be carried over winter off the sheep, and it also makes it highly improbable that the mites or their eggs will live for more than a very few weeks at any time of the year unless upon sheep or some other animal that can serve as food.

DOES DIPPING GIVE THE SHEEP A "SET-BACK?"

Sheep feeders are quite unanimous in the opinion that dipping gives the sheep a set-back. Some think it will take one, others that it will take two or three weeks of feeding to get the sheep back to the weight at the time of dipping. The following weights were made for the purpose of determining the loss occasioned by dipping in these experiments:

Table Showing Loss of Weight Caused by Dipping.

Lot	†Dates of Weighing									Dips Used
	Nov. 17	Nov. 20	Nov. 23	Nov. 25	Nov. 27	Dec. 3	Dec. 5	Dec. 8	Dec. 22	
1	51	50	50	52	50	55	53	56	59	Zenoleum, Nov. 18th.
2	52	50	51	53	51	55	55	55	58	Zenoleum, Nov. 18th and Dec. 1st.
3	52	49	50	53	50	52	48	56	58	Zenoleum, Nov. 18th and Dec. 1st.
4	53	51	51	53	51	54	56	57	59	Potassium Sulphide, Nov. 18th and Dec. 1st.
5	43	44	47	48	46	51	51	53	54	Ft. Collins Lime and Su. Dip, Nov. 18th and Dec. 1st.
6	43	43	47	47	47	48	49	50	53	Chloro-Naptholeum, Nov. 18th only.
7	42	43	46	45	43	46	47	48	50	Cooper Dip, Nov. 18th and Dec. 1st.
8	44	45	47	46	44	48	50	50	52	Black Leaf, Nov. 18th and Dec. 1st.
9	44	45	48	47	44	47	49	49	52	Black Leaf, Nov. 18th and Dec. 1st.
10	43	44	47	46	44	46	49	49	51	Black Leaf, Nov. 18th and Dec. 1st.
11	47	47	49	49	47	51	51	52	53	Not dipped.

†These weights were made by F. L. Watrous, of the Agricultural Department.

In the above table, lots 1 and 6 were dipped once, lot 11 was not dipped at all, and all others were dipped twice.

Each lot contained about forty sheep, except lot 11, which had but twenty.

Lots 1, 2, 3, 4 and 11 were all treated alike in feed, and are suitable for comparison. Lot 5, unlike any of the others, was fed on ensilage. Lots 6 to 10 were all fed grain, but differently, so that they are not suitable for comparison to determine loss from dipping. Lots 5 to 10 are included in the table only for the purpose of showing whether or not the dips seemed to have any particular injurious or beneficial effects.

The mid-day temperature for November 18, the first date of dipping, was 33 degrees, and the minimum temperatures for the three nights following were 8.8 degrees, 8.3 degrees and 13.7 degrees respectively.

COMPARISON OF LOTS ONE TO FOUR WITH LOT ELEVEN.

On November 20 the dipped lots averaged just two pounds per sheep less than on the day before dipping, while the check lot in pen 11 just held their own.

On November 23 the dipped lots averaged one and one-half pounds per sheep less than before dipping, while the check lot had made a gain of two pounds per sheep.

On November 25 the dipped sheep had gained three-quarters of a pound each to a gain of two pounds each in lot 11.

On November 27, the last weighing before the second dipping, the dipped sheep averaged three-quarters of a pound less than on the day before dipping, while the undipped lot showed neither gain nor loss.*

This would indicate a loss of three-quarters of a pound per sheep as a result of dipping and as indicated by weighing nine days after.

COMPARISON OF LOTS TWO, THREE AND FOUR WITH LOT ONE.

These four lots were as near alike in every respect as they could be made, including numbers. Lots 2, 3 and 4 were dipped December 1. The mid-day temperature was 38.5 degrees in the shade, and the minimum temperatures for the three nights following were 13.6 degrees, 28.7 degrees and 28 degrees.

On December 3 the dipped lots showed an average gain per sheep, since the last weighing, of three pounds, while lot 1 showed a gain of five pounds per sheep. This would indicate a set-back of two pounds per head as the result of dipping.

*The sudden fluctuations in weights were due to sudden changes in temperature. On the night of November 25 the temperature went down to 20.3 degrees, and on the night of November 26 it went to 11.3 degrees.

I will omit the weighings of December 5, because of the unaccountable falling-off in lot 3, probably due to an error in weighing.

On December 8 the dipped lots had made an average gain of five and one-third pounds to an average gain of six pounds in the check lot.

On December 22 we find an average gain of seven and two-thirds pounds in the dipped lot against a gain of nine pounds by the checks, indicating a set-back of one and one-third pounds in consequence of the dipping.

It is a question concerning which there might be a difference of opinion as to whether the real set-back is better indicated within a very few days after the dipping, or after two or three weeks. It is my opinion that it is best indicated in a very few days. However we may think in regard to this, the weights given above show two-thirds of a pound as the least set-back and three and one-half pounds as the largest set-back. If the least loss indicated were the real loss, it would indicate a tax of about three cents per head for dipping at the temperatures above indicated. If the sheep are worth four cents, live weight, the heaviest loss, three and one-half pounds per sheep, would mean a loss of fourteen cents for each sheep dipped.

The amount of loss will, of course, depend largely upon the degree of cold, the distance the sheep are driven, and the manner in which they are handled, but I am fully convinced from the above experiments that when the temperature is approximately what it was in the above experiments, the loss of weight from dipping will cost the owner of the sheep fully five cents per head, and this must be added to the expense of dipping to get at the total cost. It is therefore very important that the most effectual dips be used, even though they may cost more, and the dipping should be done at such time and in such manner as to do the least possible injury to the sheep. This applies more particularly, of course, to sheep or lambs that are being fed for the market.

DO DIFFERENT DIPS HAVE DIFFERENT EFFECTS?

Patent dips are often recommended as having some tonic or other beneficial effect upon the sheep, aside from killing scab, which will more than pay for its use, while such dips as lime and sulphur are sure to have some bad effect. A study of the above table does not indicate anything of that kind. It will be noticed that the bunch dipped with lime and sulphur made the largest gain of any. To be sure, this bunch was fed upon ensilage, while the others had dry food, but the rapid gain argues strongly against any specially bad effect of this dip.

The next best gain, ten pounds, was in lot 6, but these were only dipped once. The others that were fed grain, lots 7 to 10, were dipped twice and made a gain of eight pounds each.

GENERAL DIRECTIONS FOR PREVENTING AND CURING SCAB.

A little prevention will often save many dollars of expense and much trouble in dealing with this disease.

If one has sheep that are free from scab, he should not allow sheep that may have the disease to be put with them. Suspicious sheep should be kept in a yard by themselves until it is quite certain that they are free from the infection.

Persons who are purchasing lambs or sheep from a locality where scab is known to be present should not put them at once into the yards where they are to be fed for the market. They should, if possible, be kept out of these yards until dipped, at least once, and it would be better if they could be dipped twice. The experiments to determine how long the mites may live off the sheep prove that they may live at least twenty days. There is no certainty then of eradicating the disease with the best dip, even in two dippings, fourteen days apart if the sheep are put back in the old yards. A single surviving female would be sufficient, if she could find her way back on the sheep, to start the disease afresh.

Where sheep are kept the year around it will be much cheaper to dip soon after shearing when the wool is short, as it will take less material.

If lime and sulphur, or potash and sulphur are used, boil thoroughly before using in order to get a more perfect combination of the ingredients. Also, do not use more than one pound of lime to three or four pounds of sulphur, as it is the excess of lime that does the injury to the wool.

Do not get the idea that the disease may be spontaneous under any possible conditions, for it is not. As well think of horses or jack rabbits coming into existence without parents. Every sheep that contracts scab does so by getting the mites or their eggs directly or indirectly from other animals.

I wish to acknowledge the assistance received from the farm department in carrying on these experiments.

Prof. Cooke has taken much interest in the work, has helped with good suggestions, and by putting at my disposal the dipping vat belonging to the farm department and such of the farm help as was needed in carrying on the work.

A FEW INSECT ENEMIES OF THE ORCHARD.

Clarence P. Gillette, M. S.

SCALE LICE.

Colorado fruit growers may well congratulate themselves that no serious outbreak of scale insects has ever occurred in the orchards of the state, and also, that the San Jose scale has not yet been found in Colorado. But, while congratulating ourselves thus, we must not fail to take care of the few species of scale lice that are known to be present in limited localities and to take every precaution against introducing others from abroad.

HABITS AND APPEARANCE OF SCALE LICE IN GENERAL.

Scale lice are so called because they secrete over themselves, for protection, a thin, horny covering or scale. If one examines these scales in the fall or winter he usually finds them filled with minute eggs. These eggs hatch early in the spring, and the minute, wingless lice that come from them crawl about over the tree for a few days and then insert their beaks into the bark, fruit or leaves and begin to draw the sap and to grow. Once located, the lice of most species never move again. The scale soon begins to form for protection and increases in size with the growth of the louse underneath.

These scales usually imitate the bark of the tree very closely in color, so that they are often unnoticed until the tree is nearly or quite dead. A close observer will notice, however, that the bark of the tree appears rough and scaly, and that the tree lacks vigor.

HOW THE LICE ARE SPREAD.

It may seem strange that so minute a creature without wings, and one that is able to run only for a few days, can distribute itself so rapidly and be so difficult to exterminate.

These insects are scattered for the most part by being carried upon nursery stock or grafts, or even upon fruit, from place to place. They are also carried by winds and are undoubtedly carried long distances in many cases upon the feet of birds.

A FEW SCALE LICE FOUND OR REPORTED IN COLORADO.

THE SAN JOSE SCALE (*Aspidiotus perniciosus*).

This, the most destructive of all the scale lice that infest deciduous fruit trees, has been reported on a few occasions in

Fig. 2.

Figure II.—Piece of bark covered with San Jose scale, greatly magnified. (From United States Department of Agriculture, Division of Entomology, copied.)

Colorado, but I wish to assure the readers of this article that none of these reports have been corroborated. The recent reports of this scale in Mesa county were all a mistake, the scale in question being Putnam's scale, which is mentioned below.

After determining this to be Putnam's scale, I sent samples to Prof. Cockerell, of New Mexico, and to Dr. Howard, of the department of agriculture, at Washington, and both assured me that my determination was correct and that the species in question could not be San Jose scale.

This scale has been reported in no less than twenty states and territories, and is scattered from the Atlantic to the Pacific.

Fig. 3.

Figure III.—a, Pear infested with San Jose scales, natural size; b. a single scale greatly enlarged, showing the rust-colored spot at the center. (From the United States Department of Agriculture, Division of Entomology, copied.)

Our nearest neighbors reported as having it are New Mexico, Arizona, Idaho, Indiana and California.

The scales attack all parts of the tree above ground—bark, leaf and fruit. They are seldom over one-twenty-fifth of an inch in diameter, but may attain twice this size where there are only scattering individuals. Figure II. shows the appearance of

scales and young lice upon bark greatly magnified, and figure III. shows the scales on a pear, where they are represented of natural size.

PUTNAM'S SCALE (*Aspidiotus ancylus*).

This scale resembles the preceding very closely, but can usually be told from it by its darker color and the brighter or deeper rust-colored spots on the center of the scales. These two scales can only be distinguished with certainty by the use of

Fig. 4.

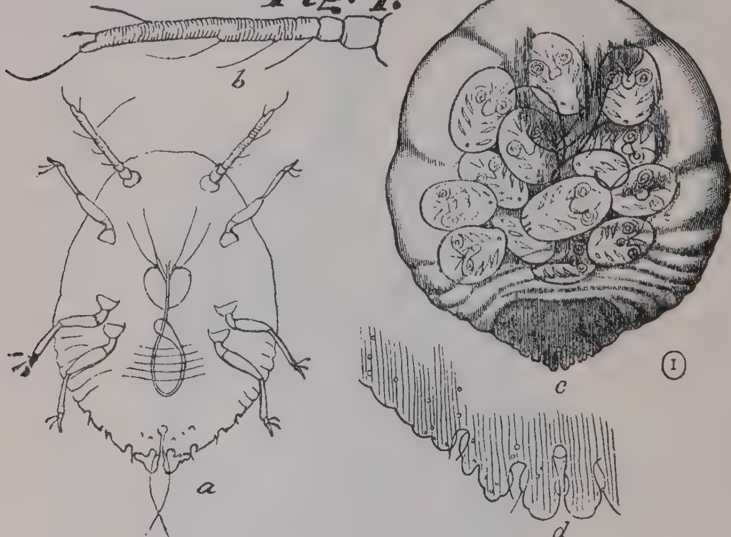

Figure IV.—a, Immature San Jose scale louse removed from the scale and greatly enlarged; b, its antenna, or feeler, still more enlarged; c, gravid female, showing young within her body; d, outline of the anal plate, greatly enlarged. (Copied from bulletin of United States Department of Agriculture, Division of Entomology.)

a compound microscope in the hands of a specialist. It is important, therefore, if either of these scales are suspected, that samples be forwarded at once to the experiment station for determination. So far as I can learn, Putnam's scale has never been a very serious pest in any part of the United States, but there is always a possibility that an insect that has formerly attracted little attention may suddenly become very abundant and injurious when introduced into a new locality. This has been known to be present in a few places in Colorado for several years. I know of one small plum orchard in Cañon City

where this scale is very abundant and is probably the cause of several trees dying. Mr. Oyler, of Grand Junction, has sent me twigs from pear and plum trees in Mesa county containing this scale in large numbers. He reports the scale to be scattered over a large territory and in many orchards, but seemingly doing but little harm, except to a single plum tree. Prof. Cockerell, of New Mexico, tells me that this scale is found in that state on oak, box-elder and cottonwood, as well as on various fruit trees. It probably occurs in many orchards in this state where it is not suspected at present.

HOWARD'S SCALE (*Aspidiotus howardi*).

This scale is a comparatively new species and was first discovered by the writer upon native plum trees at Cañon City, Colo. The scales infest both the tender bark of the twigs and the fruit. The scales are of about the same size as those of the two preceding species, but they are almost white in color and lack almost wholly the reddish center. This species seems to have decreased rather than increased since it was first discovered. If it occurs in any abundance it will probably be found conspicuous on the fruit of plum trees.

A SCALE UPON PEACH TREES (*Lecanium persicae*).

I have just recently received from Mr. A. F. Reeves, of Montrose, Colo., peach twigs from his locality infested with a large rust-colored scale about three-sixteenths of an inch long by about one-eighth of an inch broad. The scales are prominent and stand out like little galls on the bark. The scales were very abundant on the twigs sent, and, when received, March 28, the young lice had hatched and were thickly scattered over the twigs. From their size, it seems probable that they hatched last fall. Mr. Reeves reports the scales on about forty trees, so far as he can determine. As the young of this species appear all within a short time, it is probable that this scale can be easily kept in check by the use of a strong kerosene emulsion, or a strong solution of fish-oil soap soon after hatching. It will be comparatively easy to treat them while the foliage is off the trees.

Whale-oil or fish-oil soap, lime, sulphur and salt washes, resin washes and kerosene emulsion are the most common remedies used against the scale insects.

THE BROWN OR CLOVER MITE (*Bryobia pratensis*).

This is one of the worst pests on fruit trees, especially pear, apple, plum and cherry, in the mountainous districts of Colorado.

Its presence in the summer time is best noticed by the pale, sickly appearance of the foliage of the trees, by the whitish, scurvy appearance on the under side of the limbs and about the small crotches of the trees, and by the minute spider-like objects, of a dark color running about upon the bark. On examination, it will be seen that the scurvy appearance of the limbs is due to the cast skins and empty egg shells of the mites.

Although the injury to the trees is chiefly manifested in the bleached foliage, the mites will seldom be found on the leaves.

REMEDIES.

The following are the results of experiments for the destruction of both eggs and mites that were conducted by myself one year ago. During the fall, the mites deposit enormous numbers of reddish eggs upon the limbs of the trees, chiefly about the crotches. The eggs are massed together, and are plainly seen as reddish or rusty patches upon the bark:

A number of small limbs of a pear tree that were almost covered with eggs were procured from Cañon City and set out in moist earth for the experiments. Some of these I took while in Cañon City, and others were sent me by Judge W. B. Felton:

Whale-Oil Soap, in the proportions of one pound to a gallon of water, and in one-half and one-fourth this strength, killed perfectly all the eggs that were treated with it, but in the proportion of one pound to eight gallons it did little good. The newly hatched mites were killed by whale-oil soap in all strengths down to one pound to eight gallons.

Kerosene Emulsion, used without diluting (in which the kerosene was two-thirds of the mixture) and diluted with water to one-half and one-fourth this strength, killed perfectly in every case. When diluted so that the kerosene was one-sixteenth of the mixture (or one-half of the last named strength) a very few of the mites hatched. This last strength did kill, perfectly, mites in all stages when thoroughly treated with it.

Leggett's Potash Lye, in the proportion of one pound to one gallon of water, did very little good in preventing the hatching of the eggs. As near as I could estimate, it killed one-third of the eggs.

Tobacco Decoction, made by steeping one pound of tobacco in three gallons of water, had no perceptible effect upon the eggs, all hatching perfectly.

Sulphur Spray, prepared by combining three pounds of sulphur and two pounds of caustic soda and diluting to 200 gallons in water, was also used against the eggs, but without effect.

The whale-oil soap and the kerosene emulsion, being entirely efficient, one or the other should be used against this pest. As it is much easier and cheaper to make the application during the winter season, while the foliage is off the trees, this is the season that should be chosen to destroy the brown mites.

THE CODLING MOTH, OR APPLE WORM (*Carpocapsa pomonella*).

This pest causes heavier annual loss to the apple crop than any other insect. It is found in nearly every part of the world where apples are grown. In the orchards of Delta county, Colorado, it was for a number of years unknown. It is now present in all the orchard regions of the state, unless it be in some very limited and isolated places. It is not a pest that we can hope to exterminate, and orchardists can not afford to let it go unchecked.

Life Habits of the Insect—There are two, and perhaps a partial third, brood of this insect in Colorado each year. The moths of the first brood begin to appear early in the spring, and are ready to deposit their eggs in the blossom ends of the small apples as soon as the blossoms fall. The moths do not all appear at once, so that the eggs of the first brood are distributed through several weeks. If the weather is warm, the eggs will hatch in about four or five days, and the young larvæ will begin to eat in the blossom end of the apple and to burrow their way to the core, about which they feed until mature. When mature, the larvæ or worms eat a large hole to the outside, and escape to go in search of a suitable place to spin a silken cocoon and change to a chrysalis, and, a little later, to come forth as moths. This second brood of moths begins to appear about the first week in July, and in a few days, like the first brood, fly to apples or other suitable fruit to deposit their eggs. This time the eggs are often laid in the stem end of the apple or upon any rough spot where they will readily adhere. The habits of this brood are like those of the first. The later individuals do not leave the apples until they have been barreled or put in winter quarters. The winter is spent in the worm state in some protected spot, as between barrel staves, under barrel hoops, under scales of bark on apple trees, etc. Early in the spring these worms change to chrysalids, and a little later appear as moths.

REMEDIES.

On account of the habit of the larva in feeding for a little time in the blossom of the apple before burrowing to the core,

it has been found that a thorough spraying with London purple or Paris green at the correct time will destroy about 70 per cent. of them.

The proper time for spraying is immediately after the blossoms fall and *never before.* To spray before the blossoms fall is not only waste of time and material, but will also be liable to poison honey bees that visit the flowers for honey and pollen. If the spraying is much delayed, many of the worms will have already eaten their way into the fruit and be out of the reach of the poison. A second application should be made in a week or ten days after the first. If heavy rains fall, it is well to make the second application as soon as possible afterward. Should there be much rain-fall following the first or second treatment within a few days, it would pay to make a third treatment, but otherwise not. Care should be taken to throw the spray so that it will strike the blossom ends of the apples, and the treatment should be thorough. It is best to stop as soon as the leaves begin to drip.

In the eastern states, it is usually recommended to make the application in the proportion of one pound of poison to 200 gallons of water. In the dry atmosphere of Colorado I have found it very safe to apply in the proportion of one pound to 160 gallons the first time. The weaker mixture will do for the second or third applications.

A great many worms may be caught and destroyed by tying bandages of burlap or other cheap cloth about the trunks of the trees, and removing these once in a week or ten days to kill the worms that collect beneath them. This work should begin about the last week in June, and be continued until fall.

Where apples are kept in cellars, the windows and doors should have screens to prevent the escape of the moths that hatch in the cellars. Care should be taken not to take fruit barrels or boxes from storehouses or fruit dealers to the farm unless they have been thoroughly disinfected, as they often contain the larvæ of the codling moth in great numbers.

THE STATE AGRICULTURAL COLLEGE.

THE AGRICULTURAL EXPERIMENT STATION.

BULLETIN NO. 39.

A STUDY OF ALFALFA AND SOME OTHER HAYS.

Approved by the Station Council,
ALSTON ELLIS, President.

FORT COLLINS, COLORADO.

SEPTEMBER, 1897.

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A STUDY OF ALFALFA AND SOME OTHER HAYS.

Wm. P. HEADDEN, A.M., Ph.D.

The following pages are not intended as a continuation of Bulletin No. 35, although in a certain sense they form a part of that study. The work done on Bulletin No. 35, was undertaken with the view of examining the changes produced in the soil by continuous cropping to alfalfa, and, as published, claims to be a record of the work done on the plant—a study preliminary to that of the soil proper. We have been compelled, so far, to content ourselves with that work as published. There arose some questions in connection with that study which could not be discussed at the time, because our observations had not been extended enough, and we could not draw upon the results of observations still to be made. We shall, therefore, be compelled to connect portions of this bulletin rather closely with portions of Bulletin No. 35. The object of this bulletin, however, is to present a study of hays, more especially, hays made from leguminous plants—alfalfa, clover, and pease—though we shall discuss other hays to some extent.

We have attempted in this study to go beyond the routine methods of such investigations and to contribute to a better interpretation of the data obtained by the old methods in terms of much narrower and more definitely studied groups whose chemical composition, at least, if not their feeding value, is either already better known or susceptible of determination. In regard to their feeding value, too, we gain a more rational basis for evaluation than has been possible under our old methods and conventionalities.

There are many things in this bulletin which are only tentative, but they are the best results which we have obtained, and we give them as such without any apology except that we regret that our investigations have not been pushed so far as we have desired to push them.

I have no doubt but that some intelligent critic, with strongly utilitarian proclivities, will ask what value such work may be to the farmer; and possibly add, to any one else? There may also be a goodly number, other than the farmers and critics, who have but little sympathy with the class of effort recorded in these pages. I am aware that cattle will feed upon hay just as in the past and that the feeders will probably pay little heed to questions of composition as given in the fuller analyses; possibly but little more than the average man does to the same questions expressed in the terms of the analyses now in vogue. In spite of this, there is a satisfaction in finding out, with some degree of definiteness, what we mean by the old terms, such as nitrogen-free extract, crude fiber, etc. These have been useful terms, very convenient ones, under which to include much that we did not know about a fodder. If this line of work has no other commendation, it is an attempt to find out how much we do not know, and to which we have made no pretense of knowledge, and also some of our misconceptions.

In the closing paragraphs of Bulletin No. 35, I called attention to the variations in the composition of alfalfa hay grown in different localities, and the analyses given cover a period of about ten years—1886-1896. It would seem that the analyses recorded in this period ought to represent with a fair degree of accuracy the composition of the plant as grown in this country; but there is such a wide range in its composition that the suggestion is near at hand that the variation in composition is due to climatic conditions, and not to differences in the soils. We have extended our observations to observe these effects, and not simply to increase the number of analyses of alfalfa, which seems to us altogether useless.

It is true that there are variations in the climate of a locality from year to year; still the climatic conditions of a given locality are, in the main, quite constant in their general character, and we reduce the climatic effects to this minimum by making observations upon the plant grown in the same locality, and, contrariwise, we gain information on this very point by taking our samples from the same plot of ground.

Our samples of alfalfa hay showed, in comparison with

samples from other states, a great uniformity in composition. The crude protein in the first cutting hay had a range of less than two per cent.—from 14 to 15.9 per cent. These samples represented hay made from alfalfa grown with and also without irrigation; also such as had been grown upon high land as well as that which had been grown upon low land. The crude fiber in these samples had a very much greater range in percentage—from 32 to 40 per cent.—than the crude proteids. This may have been partly due to a less degree of sharpness in the method of determination, but we judge it to be due to an actual difference in the samples. These are narrow limits when compared with those shown by analyses representing different states, in which we have, for the crude protein, a range of 14.6 per cent.—from 11.1 to 25.7 per cent.; and for the crude fiber, a range of 24.5 per cent., or from 15.4 to 39.97 per cent.

In the second cutting again we find a narrow range, but wider than in the first cutting. The extreme range for the crude protein is 5.6 per cent., and, excluding an exceptional sample with 18.47 per cent., this range becomes 3.5 per cent. The crude fiber for this cutting has a range of about 12 per cent.—from 26.16 to 38.08 per cent.

The range for the proteids in the third cutting is 3.5 per cent., and for the crude fiber, 10 per cent. These samples were all of hay as put into the mow or stack.

A study of the analyses published up to 1896, fails to furnish any general composition for this fodder, and we cannot discern any patent and adequate reason for this. In the New Jersey Experiment Station Report, for 1886, the lowest amount given for crude protein was 16 per cent., and the highest for crude fiber was 35 per cent.; as given in the Report for 1888, eight samples are recorded; the lowest of these in proteids has 15.24 per cent., and the highest in crude fiber has only 24.34 per cent. The same observations are true of the Texas samples, except that we find a greater difference between the highest and lowest in the case of both of these constituents; for the proteids, from 15.31 to 25.75 per cent., and for the crude fiber, from 16.64 to 34.23 per cent. If we take the published analyses of Colorado samples we shall find a like variation.

Even the most unfriendly critic of the methods or the operators using them, cannot possibly explain these differences by the weaknesses of either or both of these. In order to obtain light upon this point, we have studied the three cuttings of 1894, the first cutting of 1895, and the three cuttings of 1896. The methods employed in the analyses

and the operators during the period of these experiments were the same, so the results are comparable, and are free from divers personal equations. There is, it is evident, much even in these results which would be more satisfactory if more uniform; still they show that this fodder, as grown in this State, has a pretty uniform value. The season of 1896 was not a very favorable one, and we judge that we have as great a variation, due to seasonal differences, as we have reason to expect. The samples for 1896 were all taken from the same piece of land with one exception, and this one differs so slightly from the others in composition that it is fortunate, rather than otherwise, that it was obtained from another locality.

Some of the samples of previous years were taken from nearly the same ground as those of 1896, so that they also have value indicative of how much alfalfa hay cut from the same land may vary in chemical qualities from year to year.

Three samples of each cutting were taken, representing different stages of maturity, regard being had to their respective influences upon the quality of hay produced.

The results of the analyses are as follows:

Cutting.	Condition of the Plants.	Air Dried Hay.							Thoroughly Dried Hay.					
		Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.
1	Coming in bloom.	7.22	9.81	1.15	15.16	36.49	30.17	2.426	10.57	1.24	16.47	39.43	32.29	2.624
1	In half bloom	7.92	11.89	1.26	14.46	32.80	31.67	2.310	12.92	1.36	15.70	35.62	34.41	2.508
1	In full bioom....	6.38	10.57	1.31	15.73	34.91	31.11	2.516	11.29	1.40	16.80	37.29	33.23	2.687
	Average..	**7.17**	**10.76**	**1.24**	**15.12**	**34.73**	**30.98**	**2.417**	**11.44**	**1.33**	**16.32**	**37.44**	**33.31**	**2.606**
2	Coming in bloom.	4.43	12.70	1.71	17.68	27.47	36.01	2.858	13.28	1.78	18.50	28.75	37.69	2.990
2	In half bloom....	9.48	11.34	1.50	17.14	24.27	36.27	2.743	12.53	1.65	18.94	26.81	40.08	3.032
2	In full bloom....	8.56	9.91	1.78	16.41	27.11	36.24	2.625	10.84	1.95	17.94	29.64	39.64	2.880
	Average..	**7.49**	**11.32**	**1 66**	**17.08**	**26.28**	**36 17**	**2.742**	**12.22**	**1.79**	**18.46**	**28.38**	**39.13**	**2.967**
3	Coming in bloom.	8.64	12.24	1.72	16.53	24.30	36.57	2.645	13.39	1.88	18.09	26.59	40.04	2.894
3	In half bloom....	7.43	11.07	1.52	15.51	30.55	33.92	2.482	11.96	1.64	16.76	33.00	36.65	2.681
3	In full bloom	8.36	10.66	1.83	15.59	30.18	33.38	2.495	11.63	2.00	17.01	32.94	36.42	2.722
	Average..	**8.14**	**11.32**	**1.69**	**15.88**	**28.34**	**34.62**	**2.540**	**12.33**	**1.84**	**17.29**	**30.84**	**37.70**	**2.766**

The analyses of the first cutting agree with those of preceding years, but the series representing the second cutting is not concordant with previously obtained results. The

most marked deviations are in the higher amounts of crude protein and in the lower percentages of crude fiber. The third cutting is far more representative of the plants than the samples of the previous years, because this set of samples of the third cutting is complete in itself. The samples, too, represent the whole plant, without loss of leaves and stems, cut in the very best condition. The third cutting of 1894, the only previous year in which samples of this cutting were analyzed, was represented by samples of hay as it was taken from the field.

There is, in the 1896 samples, a superiority in quality over the samples of 1894. This is most marked in the third cutting, but, as has just been stated, a portion of this difference may be attributed to the fact that the samples were more nearly comparable to those of the other cuttings. The crude protein is higher for each of the three cuttings and the crude fiber is lower, while the nitrogen-free extract is slightly higher, though not so much so as one, at first glance, would think.

The season of 1894 was favorable for the making of heavy crops. The first cutting was very heavy, the stems were exceptionally stout, and the growing period was long. These conditions were reversed in 1896, and I am inclined to attribute the differences observed almost wholly to this cause. The second crop of 1896 grew quickly and resembles in composition samples of the first cutting, cut on May 5th, 1895, rather than the other second cutting samples. Both samples matured rapidly; they were both high in ash, high in crude protein, and low in crude fiber. The first cutting of 1895 (May 5th), is even higher in protein than the second cutting of 1896, and quite as low in crude fiber. This seems to me to indicate that the rate of maturing which, of course, depends upon the seasonal influences, determines, very largely, the composition of the hay produced. It is quite evident that a quickly maturing crop will probably be less in quantity than a more slowly maturing one of the same kind. In 1894 we collected samples from a variety of soils to see whether any differences in the quality of the hay were to be attributed to this cause. The results are in favor of an affirmative answer, but in no very marked degree. I speak of soils which have received no fertilizers. It is a demonstrated fact that these have an effect upon the quality of the hay, and I have elsewhere noted the susceptibility of the alfalfa plant to the direct application of manures. A fertilized soil, or one naturally rich, which, under ordinary conditions, is equivalent to a vigorous growth extended

over a longer period, tends to increase the percentages of ash, protein, and crude fiber. In the second cutting of 1896, the ash and protein are high, but the crude fiber is low and the crop was light.

The conditions obtaining later in the season of 1896, were more nearly normal for our locality and the third cutting grew for a longer period, matured more slowly, and, while the proteids are high, we have an increase of about six per cent. in the crude fiber of the later sample. There is no such increase in the other series for this or for preceding years. While there is in general an increase in the percentage of woody fiber, with the development of the plant, we have found it neither so great nor so regular as is shown in Bulletin No. 8, of this station, and also by others. We speak of the plant during the period in which it is fit for making hay. In this instance, however, we have a decided increase which, I believe, is fully accounted for by the explanation offered, i. e., the season conditions which determine the rate at which the plant matures. If this view be correct, it follows that the same piece of ground will produce hays of different qualities in different years even when we take hays of the same cutting, and the total of these seasonal influences is correctly indicated by the differences in the composition of the respective samples. This influence seems to be large enough to determine the relative desirableness of the different cuttings which, under ordinary conditions, stand pretty close together. In speaking of the crop of 1894, we state that the first and second cuttings are about equal in value, so far as the proteids are concerned, and subsequently we call attention to the fact that, if we reject an entirely green sample because of its immaturity, the results are then in favor of the second cutting. The seasonal effects do not have to be very great to determine which of the cuttings shall have the more desirable composition.

The following table, presenting the averages for the respective cuttings for the years 1894, 1895, and 1896, will serve to make these differences plain and show that for a given district there is a comparative constancy in the composition of this fodder.

These averages, to which is appended averages for the usual three cuttings, taken from Bulletin No. 48 of the Utah Agricultural Experiment Station, which I have recalculated to a common water content of 7.5 per cent., instead of 12 per

cent., to facilitate their comparison with our Colorado samples, are as follows:

Cutting.	Year Collected.	Source of Sample.	Number of Samples.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-free Extract.
1	1894	Laboratory samples..............	9	6.21	10.03	1.55	14.85	36.28	31.08
1	1894	Farm department................	3	7.59	11.19	*3.59	14.92	28.10	34.61
1	1895	Laboratory samples	4	6.49	10.61	1.50	15.13	34.03	32.24
1	1896	Laboratory samples..............	3	7.17	10.76	1.57	15.12	34.73	30.65
1	1896(?)	Utah †..........................	3	7.50	9.78	2.59	14.29	28.41	37.43
		Average	22	6.99	10.47	1.80	14.86	32.31	33.57
2	1894	Laboratory samples	5	5.94	10.24	1.41	14.43	34.15	33.73
2	1894	Farm department................	3	8.05	10.48	1.53	13.99	31.97	33.98
2	1896	Laboratory samples..............	3	7.49	11.32	1.66	17.08	26.28	35.25
2	1896(?)	Utah..........................	3	7.50	8.78	2.13	15.23	31.18	35.28
		Average	14	7.24	10.21	1.68	15.18	30.90	34.79
3	1894	Laboratory samples..............	2	5.93	9.83	1.46	13.01	37.01	32.74
3	1894	Farm department................	3	5.63	10.07	1.43	13.47	33.70	35.70
3	1896	Laboratory samples....	3	8.14	11.32	1.69	15.88	28.34	34.62
3	1896(?)	Utah..........................	3	7.50	8.58	1.73	11.95	32.79	37.45
		Average	11	6.80	9.95	1.58	13.81	32.98	34.90

* Not included in the average.
† Taken from Bulletin No. 48, Utah Expt. Sta., and recalculated to a basis of 7.5 per cent. moisture.

We see from the preceding table that, for the first cutting, representing three years and four soils, the composition is practically constant, the greatest variation being in the percentage of crude fiber. This difference, however, is no greater than may be found in different samples collected from the same field on the same date. The results for the second cuttings are not so uniform, and I think that we have here exhibited the maximum variation, which may reasonably be attributed to differences in the seasons, amounting to three per cent. for the protein, and eight per cent. for the crude fiber.

The averages for the third cuttings show the same irregularities that are observed in the second cuttings. My samples for the season for 1896 are consonant with the general

results in showing the second cutting to be, in point of composition, the preferable one. While these samples are the farthest removed from the general averages, they differ from these less than samples of the same cutting in any year may differ from one another. I am convinced that the variation in the different cuttings from year to year is dependent mostly upon the seasons, and is in no case very large, very much smaller in fact, than I had supposed.

CHANGES IN COMPOSITION OF OLD HAY.

That fresh hay, i. e., hay which has been in the mow or stack from one to nine months, is preferable to hay which has been there for a longer time, is generally conceded, whether there is any good ground for the general belief or not. The samples which we have used to study this question were prepared for analysis, put in glass bottles, and from one to two years allowed to elapse between the two determinations. These samples were stored in a dark cupboard in a dry room which was as close an imitation of the conditions prevailing in a mow as we could produce. The samples were air dried when put away, but they evidently changed in the amount of moisture present, as it was found necessary to redetermine the moisture in all of the samples. I expected that the crude protein would be most susceptible to changes, and therefore determined upon making a series of nitrogen determinations from which to judge of the amount of deterioration. We found that we were wholly wrong in our idea that the nitrogen would be the most sensitive measure of any changes, at least for the conditions under which our samples were preserved. It may be noticed here that every sample had increased in the amount of moisture contained; only one remained unchanged and this was the only sample which showed a diminution in the amount of nitrogen present. The changes, with this one exception, were all in the same direction—to an increase in the percentage of nitrogen. We examined seventeen samples and found but one exception to this rule. The bottles containing these samples were stoppered and sealed with paraffin, so it would seem very improbable that the whole seventeen should fail to keep out the atmospheric moisture. We give the moisture determinations to show how marked this increase was and how general the rule, there being only one pronounced exception to it. The first column contains the figures representing the hay in 1894, and the second in 1896.

	1894. Per cent.	1896. Per cent.
1	4.49	8.68
2	4.17	8.12
3	7.86	7.81
4	6.29	8.84
5	6.30	8.54
6	5.29	6.91
7	4.70	7.27
8	4.31	6.68
9	4.40	7.61
10	6.61	7.17
11	5.81	7.94
12	6.06	6.52
13	8.87	8.26
14	7.14	8.17
15	7.46	8.72
16	3.77	4.41
17	7.60	8.62

If this increase of moisture had not been accompanied by an increase in the percentage of nitrogen in the dry matter, I would have attributed it, in spite of the fact that the bottles were sealed, to the absorption of moisture.

NITROGEN IN NEW AND OLD HAY.

	1894. Per cent.	1896. Per cent.
1	2.422	2.989
2	2.604	2.878
3	2.740	2.132
4	2.459	2.514
5	2.181	2.770
6	2.205	2.382
7	2.037	2.500
8	2.149	2.627
9	3.013	3.037
10	2.572	2.657
11	2.005	2.912
12	2.401	3.051
13	2.366	2.588
14	2.047	2.426
15	2.522	2.702
16	2.562	2.680
17	2.638	2.657

In the above table the percentages are calculated on the dry material. The two series, of course, represent the same samples. There is no regularity in the amount of the increase in case of either the water or the nitrogen. This

study is not sufficiently extended to justify fuller discussion, but a study of my notes indicates that the samples cut in early bloom have suffered the least change; also that the change is less in one year than in two years. The last three samples were only one year old at the time the analyses were made.

The increase in the percentage of water in the sample and the increased percentage of nitrogen in the dry matter seem to me to point to a transformation in the constituents included under the term nitrogen-free extract. It is certainly beyond question that the nitrogen cannot be increased by absorption, and it is improbable that the material which we class as crude fiber will break down rapidly enough to account for the formation of so much water, in some instances four per cent., especially when we remember its ability to resist the action of dilute acids and alkalies.

Our experiments indicate that there is no loss of the proteids, but that chemical changes take place to a considerable extent in some of the other constituents, probably in those complex and less stable compounds grouped under the head of nitrogen-free extract and frequently spoken of as carbohydrates. The apparent increase of nitrogen is easily accounted for by the elimination of water and probably of other compounds also, as oxides or hydrides of carbon.

We have in the above explanation of our facts, I think, a full and satisfactory explanation of such facts as have been observed relative to the saving of hay, for instance, by putting it in a mow, in which case the loss of weight is much less than when the hay is kept in the stack. Our application of the observed facts would be, that, other things being equal, hay preserved in the stack is more freely exposed to influences which promote these changes in the less stable constituents of the hay; and the loss due to these changes becomes noticeable.

I understand that it is found almost impossible, in practice, to feed out anywhere near the amount of hay for a ton put in a stack, that is usual to feed out when the same weight is put into a mow. It is evident that some hays may age very much faster than others, due to kind of hay—alfalfa, clover, timothy, etc.—also due to development at time of cutting, manner of storing, and other conditions.

There is, perhaps, a suggestion in the figures representing the percentages of water found in 1896, that the samples in 1894 did not really represent air dried hay and that in the course of the intervening year and a half, or more, they had really become such. This receives support from

those samples prepared in 1896, which have about the same percentage of water. But this compels us to assert that the sealing of the bottles was of no avail at all and disregards the increase in the percentage of nitrogen in the dry matter, which seems to us fully established. The differences cannot be attributed to the different methods of determination, nor yet to the operator, as the same person, my assistant, Mr. Ryan, made the two series of determinations by the same method and always in duplicate.

While this subject may be more interesting to the investigator in the domain of agricultural science than to the practical agriculturist, we regret having been unable to pursue it to no greater extent.

ARTIFICIAL DIGESTION OF ALFALFA HAY.

It is not our purpose to discuss the relative merits of artificial compared with animal digestion, but if we confine ourselves to the question of the pepsin digestion of the albuminoids, it is certainly more agreeable, more satisfactory in that it can readily be applied to a much larger range of samples in a short time, and has the further advantage that the different samples can be subjected to the same conditions. The commercial pepsin preparations may vary in quality very greatly, but the pepsin can be tested before it is used quite as easily as any other chemical reagent.

We undertook the investigation to discover whether there is any difference in the digestibility of the three cuttings of alfalfa hay or in alfalfa hay of different ages. The samples employed in this work were new hay, one-year-old hay, and two-year-old hay. These terms, new hay, one-year-old hay, and two-year-old hay, are to be understood in their ordinary sense, and not that a sample of alfalfa was made into hay and its digestibility determined forthwith, for such was not the case. The samples were taken in the years of 1894, 1895, and 1896, and the determinations were made in the last year.

THE METHOD.

We followed the method in general use—digestion with a dilute hydric chlorid solution of pepsin. After an extended series of experiments with coagulated egg albumen, we adopted the following method as giving the best results. We dissolved five grams of scale pepsin in one litre of two-tenths per cent. hydric chlorid and to five grams of alfalfa, ground as fine as possible, we added 150 cc. of the pepsin solution, and digested it for eight hours at forty degrees C., adding, during the eight hours, .7 grams of hydric chlorid.

After the digestion was completed, the alfalfa remaining was filtered off, washed free from chlorid, and the residual nitrogen determined by Kjeldahl's method.

The period of eight hours was decided upon, because we found in experimenting with the egg albumen that we obtained a complete solution in this time and seldom in a shorter period, and if we allowed it to stand longer a precipitate began to form which was not very readily gotten into solution again. This method contains an error in that it shows any soluble amids which may not be assimilated by the animal as digestible. As the amount of amids is quite large in some of the samples, this may give rise to comparatively large errors. This error is not wholly eliminated in the case of animal digestion. The amount of amids had been previously determined in the samples of 1894 and 1895. They amounted to 10.85 per cent., for the first cutting, 19.93 per cent., for the second cutting, and 5.03 per cent. (one sample only) for the third cutting. The amids were not determined in the samples for 1896. The co-efficients of digestion obtained do not show any variation corresponding with the amids found. The sample of second cutting in half bloom shows a lower digestion co-efficient than the one following it in full bloom, and still lower than the one preceding it in half bloom, and yet it contains amid nitrogen corresponding to 29.47 per cent. of its crude protein. The others contained much less nitrogen in this form, the amount corresponding to 18.84 per cent., and 17.82 per cent. of the crude protein in the respective samples.

The co-efficients of digestion for the proteids in alfalfa, as determined by animal digestion, are as follows:

In green alfalfa, 78-83; mean of six trials, 81.

Carefully dried alfalfa, 70-83; mean of six trials, 80.

Alfalfa hay, early bloom, best quality, 71-83; mean of twenty-six trials, 76.

Alfalfa hay, full bloom, 66-73; mean of ten trials, 68.

Alfalfa hay, carefully dried, 78; mean of two trials, 78.

Alfalfa hay as given in Colorado Bulletin No. 8, 77.

Alfalfa hay as given by N. Y. Exp. Sta., 69.

Considering these seven averages, we observe that five of them fall between 76 and 81 per cent.

The only statements that I recall to have seen concerning the relative efficiency of animal and pepsin digestion is to the effect that the pepsin is rather higher, usually dissolving from 2 to 6 per cent. more of the crude protein than is taken up by the animal. If we take the average of the five most nearly agreeing means, given above, we obtain 78.4

for the co-efficient of digestibility for crude protein in alfalfa hay, or 75.6, if we include all the means given. It seems probable that the five closely agreeing ones are nearer to the truth than the two whose average is ten per cent. below the average of the five, and I take it that the 75.6 is a less representative co-efficient than the 78.4.

We record in the following table the results obtained by pepsin, or artificial digestion, of the first, second, and third cuttings of the year 1894; the first cutting of 1895, and the three cuttings of 1896.

ARTIFICIAL DIGESTION OF PROTEIDS IN ALFALFA HAY.

Number.	Number of Cutting.	Condition at Time of Cutting.	Total Nitrogen.	Nitrogen not Digested.	Nitrogen Digested.	Co-efficient of Digestion.
		Samples gathered in 1894—				
1	1	Plants not in bloom	2.878	0.574	2.304	80.07
2	1	Plants not in bloom	2.132	0.420	1.712	80.30
3	1	Plants in half bloom	2.514	0.520	1.994	79.30
4	1	Plants in full bloom	2.989	0.590	2.399	80.26
5	1	Plants in full bloom	2.770	0.522	2.248	81.15
6	1	Plants in early seed	3.051	0.643	2.408	78.92
7	1	Plants in full seed	2.500	0.595	1.905	76.02
8	2	Plants coming in bloom	3.037	0.522	2.515	82.81
9	2	Plants in half bloom	2.657	0.542	2.115	79.60
10	2	Plants in full bloom	2.627	0.502	2.125	80.89
11	2	Plants in full bloom	2.382	0.495	1.887	79.18
12	3	Hay, College farm	2.912	0.514	2.398	82.69
		Samples gathered in 1895—				
13	1	Plants in full bloom	2.588	0.499	2.089	80.72
14	1	Plants in full bloom	2.702	0.508	2.194	81.20
15	1	Plants in full bloom	2.680	0.510	2.170	80.97
16	1	Plants in full bloom	2.657	0.540	2.117	79.68
		Samples gathered in 1896—				
17	1	Plants coming in bloom	2.624	0.580	2.044	77.89
18	1	Plants in half bloom	2.514	0.512	2.002	79.60
19	1	Plants in full bloom	2.687	0.498	2.189	81.69
20	2	Plants coming in bloom	2.990	0.664	2.326	77.79
21	2	Plants in half bloom	3.032	0.664	2.368	78.10
22	2	Plants in full bloom	2.870	0.559	2.311	80.87
23	3	Plants coming in bloom	2.894	0.635	2.259	78.06
24	3	Plants in half bloom	2.681	0.567	2.114	78.85
25	3	Plants in full bloom	2.722	0.596	2.126	78.15

It is observable throughout the series that the samples in full bloom have a slightly higher co-efficient than the other cuttings with only one exception, which is in favor of a very early cutting. The third cutting hay (No. 12) is not an exception, as the plants were near or at full bloom when cut.

We have already given the average co-efficient of alfalfa hay of all kinds, determined by animal digestion, as 78.4. The highest and lowest individual results in the experiments which we have accepted as most representative are far apart, ranging from 70 to 83, a maximum difference of 13 per cent. of the proteids. The maximum difference in our series, debarring No. 7, because it was too ripe for hay, is five per cent. of the proteids, or, including all samples, it is approximately ten per cent. of the proteids. The co-efficients given by cuttings are as follows: For 1894, first cutting, 79.43; second cutting, 80.62; third cutting, 82.69; for 1895, first cutting, 80.64; for 1896, first cutting, 80.14; second cutting, 78.81; third cutting, 78.85. The average for all the cuttings, made in the three years, is 79.79, which is in excellent agreement with the results obtained by animal digestion.

The results taken by years are as follows: For 1894, hay two years old, 80.91; for 1895, hay one year old, 80.64; for 1896, new hay, 79.27, from which it is clearly apparent that the proteids have not lost any of their digestibility, and from this standpoint hay which is one or even two years old, is quite as good as new hay. The nitrogen determinations given on page 11 show a relative increase of nitrogen, so that whatever changes take place in hay in the mow, during the course of one or two years, they do not cause any deterioration in either the amount or digestibility of the proteids. The importance of this will be more apparent to the average feeder when he considers that the proteids make up between 1-7 and 1-6 of the total weight of the hay, and that in value it is equal to over one-third of the hay. This is based upon two and three-tenths cents per pound for proteids, one and fourteen-hundreths cents per pound for fats, and ninety-four hundreths cent per pound for crude fiber and nitrogen-free extract. (Conn. Exp. Sta., 1893.)

PENTOSANS.

It has been customary until very recently, and is still the general practice, to divide the food elements of plants into the four groups, fats, crude fiber, nitrogen-free extract,

and crude protein. We have known how to divide the protein into two classes of nitrogen compounds, which are probably of very unequal value as food constituents, and, while we have been accustomed to speak of nitrogen-free extract, as though it had some definite individual character, we have done so with the understanding that it included gums, starch, sugar, etc., etc., and the same has been the case with the term crude fiber. We know that it contains cellulose and other allied compounds which differ from one another in composition, and probably to even a greater extent in their physiological value. Several of these compounds give, under similar treatment, a characteristic product which becomes the measure of the amount of them present. While it is exceedingly improbable that there is in the hays, to be mentioned later, only one furfurol-yielding complex, I have, for the sake of greater simplicity, calculated the results obtained in terms of xylan, as this is probably the predominating group yielding the furfurol. These substances are given in the present prevailing method of stating fodder analyses, partly as crude fiber and partly as nitrogen-free extract. The former, according to our results, contains from one-half to three-fourths of them and the latter the rest. We frequently speak of the nitrogen-free extract as almost equivalent to carbohydrates soluble in water; this custom has the merit of easy expression and convenience. It is not our province to determine the relation of these constituents to the economy of the plant, and it does not effect our object in the least to determine this, but simply to determine the quantity of them present. It seems highly probable that, as they are more reactive than the celluloses proper, they play a more important part in the nutrition of animals than these, but are inferior to the carbohydrates proper.

We have followed in our furfurol determinations the method as laid down by the Association of Official Agricultural Chemists, except that we dissolved the hydrazone in ether alcohol.

The samples of alfalfa hay used in these determinations were the same samples of which fodder analyses have been given in Bulletin No. 35 and in the early part of this bulletin. The results in the following table are calculated on dry matter. The crude fiber found in these samples is also given.

XYLAN IN ALFALFA HAY.

No.	Cutting.	Condition of Plants.	Xylan.	Crude Fiber.
		Samples gathered in 1894—		
1	1	Plants not in bloom	9.44	37.04
2	1	Plants in full bloom	9.86	38.50
3	1	Plants in full bloom	10.94	42.77
4	1	Plants in early seed	13.77	40.13
5	1	Plants in full seed	14.42	48.38
6	2	Plants coming in bloom	14.03	34.13
7	2	Plants in half bloom	12.43	39.19
8	2	Plants in half bloom	14.50	39.88
9	2	Plants in full bloom	12.48	39.64
10	3	Hay, from College farm	10.54	39.36
11	3	Hay, from Rocky Ford	12.34	34.27
		Samples gathered in 1896—		
12	1	Plants coming in bloom	14.24	39.43
13	1	Plants in half bloom	11.09	35.61
14	1	Plants in full bloom	9.12	37.29
15	2	Plants coming in bloom	8.88	28.75
16	2	Plants in half bloom	9.10	26.81
17	2	Plants in full bloom	11.01	29.64
18	3	Plants coming in bloom	10.11	26.59
19	3	Plants in half bloom	11.76	33.00
20	3	Plants in full bloom	12.91	32.94
		Parts of Plants—		
21	3	Leaves	9 29	13.00
22	3	Upper part of stems	13.32	....
23	3	Lower part of stems	11.25	....
		Crude Fiber—		
24	3	From the leaves	12.73	....
25	3	From the upper part of the stems	13.46	....
26	3	From the lower part of the stems	15.41	33.07

The percentage of crude fiber is given in the first twenty analyses to show that there is no constant relation between it and the xylan in the whole hay. This becomes more apparent when we examine the results of 24, 25, and 26. If we calculate the xylan found in 24, to percentage of the total xylan in the original sample, assuming thirteen per cent., as the average for crude fiber in leaves, we find it

corresponding to 17.69 per cent. And in like manner for 25 and 26, assuming 33.07 per cent., as the percentage of crude fiber in the stems, we find the xylan in 25 corresponding to 33.33 per cent. of the xylan in their original sample, and in 26 it amounts to 45.29 per cent. The method of preparation of the crude fiber was not the same in each case and these samples are not strictly comparable as far as the method affects the question.

If we express these results in the more direct manner of stating the percentage of the total xylan removed by the successive digestions with sulphuric acid and caustic soda, we find that in the case of the leaves 82.31 per cent. of the xylan was removed; in the upper part of the stems, the small ends, we have 66.66 per cent. removed, and in the lower and more woody part we find that 54.71 per cent. has been removed. While it may not be rigorously correct that the amount of those substances which yield the furfurol are proportional to the furfurol obtained, it may be assumed to be true for the aggregate which we have in hay, and an examination of the percentages of xylan shows that they, like the proteids, depend probably not so much upon differences of soil, as upon seasonal differences. Taking the three cuttings of 1896, the second and third show an increase in the xylan as the plant matures, but the first cutting shows the opposite. The samples collected in 1894 are equally indefinite. We are, however, justified by analyses 21 to 26, in concluding that there are several complexes present which yield furfurol, and they offer different degrees of resistance to the alternate action of acids and alkalies. The complexes yielding more readily to the action of these agents predominate in the leaves, forming nearly nine-tenths of the whole amount, whereas in the stems they form only about one-half.

Analyses to be given subsequently indicate that there is still another distinction, for some of them are removed by extraction with alcohol and water, while others are not. The conditions, under which the work recorded in these paragraphs was made, were as uniform as possible, for it is evident that this is necessary in order that our results shall have the same significance.

COMPARISON OF LEGUMINOUS HAYS BY NEW METHODS.

It has long been felt that our methods of fodder analysis leave much to be desired, and, while they are very helpful in forming a judgment of the value of a hay, they have not been conclusive. I do not claim that the present effort

leads to much more satisfactory conclusions, but it is an effort to get a more definite and detailed view of the components of hay. Heretofore we have been accustomed to speak of carbohydrates and water soluble substances as though starch, sugar, etc., were present in abundance. We may not be able to show what the substances are which we have been calling by these names, but we can show how much sugar and starch are present and that we must find some other names for the rest. As an example of the inadequacy of a fodder analysis to enable us to judge of the value of a grass as a fodder plant, I may cite the case of *Stipa viridula var. robusta*. My attention was called to this grass by Professor C. S. Crandall, who requested me to analyze it. The grass is one familiar to people of the West, growing in bunches among the foothills. For comparison we give an analysis of a hay taken from the Year Book of the Department of Agriculture for 1894:

	Hay, mixed grasses, and clover. Per cent.	Stipa viridula. Per cent.
Water	13.20	5.53
Ash	4.40	5.76
Protein	5.90	8.91
Fiber	29.00	39.60
Nitrogen-free extract	45.00	38.24
Fat	2.50	1.96

The analysis of the hay is an average analysis, while that of the Stipa is a single analysis of a small sample; but it suffices to show that hay made from this grass ought to be preferable to a mixed hay, that is the average article, but cattle will not eat the Stipa, and horses feed on it with great moderation. The analysis is correct in regard to the composition of the fodder, but stock do not like it, and hay which animals will not eat, except when driven to it by excessive hunger, does not answer the purposes of a first-class fodder, however good an analysis may show it to be. We have a parallel in the composition of our native hays and of alfalfa. All stock, so far as I know, eat alfalfa greedily, and its analysis shows it to be an excellent fodder for general purposes, and yet it possesses qualities which make it, in general estimation, a poor fodder for work or road

horses, and it sells in the market at about one-half the price of native hay.

It is not probable that chemical analyses will ever be able to discover these properties which are, partly at least, physiological; still we may yet learn more about the subject and become able to form a better judgment than we can at present.

In the following I have endeavored to obtain a better knowledge of the hays made from alfalfa, clover, the field pea, and native hay.

For the methods followed I am indebted mostly to the work of Cross and Bevan, but I have also drawn upon whatever literature has been accessible to me.

The process of analysis is almost identical with that proposed by Professor Stone, i. e., successive extraction with boiling alcohol, cold water, diastase, boiling dilute acid, boiling dilute alkali, and treatment of the residual fiber with chlorin. The reducing power of the products of hydrolysis were determined by means of Fehling's solution and estimation of the copper by means of potassic cyanid solution. The chief difficulties arose from the large amounts of coloring compounds presents in some of the extracts. The reducing power of some of these solutions was diminished by treating them with basic lead acetate, though I could find no sugar in the precipitate.

The preparation of the sample of hay for this process is of considerable importance. If there are larger pieces of stems, it is difficult to free the cellulose from lignones and the cellulose will give the phloroglucin-hydrochloric acid reaction. I found this markedly the case with alfalfa, clover, and the pea vines, but not so with the native hay. If the sample is ground to a uniformly fine powder this is not the case, and the cellulose will not react with the phloroglucin solution. That this is the correct explanation of the cause of the reaction, and that it is not due to the inability of the chlorin to remove the lignone groups, is clearly observable when the reaction is watched under the microscope. The small pieces will remain uncolored, and the large ones will be observed to have an outer uncolored portion inclosing a colored nucleus.

The alfalfa selected for this analysis was a sample of new hay made from plants coming into bloom.

The following are the results obtained:

	Per cent.
Invert sugar	none
Sugar	trace
Dextrin	trace
Starch	1.11
Xylan, inverted by dilute acid	3.76
Xylan, soluble in alkali solution	0.15
Lignones, rendered soluble by chlorin	6.66
Cellulose	25.59
Moisture	7.21
Ash	9.81
Ether extract	1.15
Proteids	15.16
Soluble in alcohol	13.87
Soluble in water (starch, etc., deducted)	11.88
Not determined	3.65
	100.00

The substances dissolved by water are only partly precipitated upon the addition of a large excess of alcohol. The amount precipitated was 8.2 per cent. of the sample. It did not prove to be dextrin. This caused me some trouble and I increased the amount of hydric chlorid used in inverting and increased the time of heating, at the temperature of boiling water, to one and a half and even to two hours. I did the same with the starch solution.

A portion of the sample was extracted successively with 95 per cent. alcohol and cold water—two grams of the sample, 24 c. c. alcohol, and subsequently 40 c. c. cold water—the residue was washed with cold water and the remaining nitrogen determined. We found 1.554 per cent., calculated on the air dried substance; whereas the total nitrogen was equal to 2.426 per cent., a difference of .672 per cent., which is over 27 per cent. of the total nitrogen. This is rather more than we have found in any sample in the form of amid nitrogen; but inasmuch as some samples have furnished nearly as much as this, we are led to believe that it is the amids, principally if not wholly, which are soluble in water. There is in this no oxidation and fermentation such as take place in the weathering of hay, and the two processes are not equivalent, though they may be similar to some extent.

The crude fiber contained, in this instance, .33 per cent. nitrogen, or, roughly calculated on air dried hay, about .11 per cent. This was neglected in the further calculations. Of the crude fiber itself 78.96 per cent. was cellulose, and 21.04 per cent. was lignones.

The sample of clover hay was two years old. The plants were cut when the heads were half turned, and the whole plant was cured without the loss of any leaves or stems. The sample, as judged by physical properties, is somewhat above the average of clover hay in quality. The ordinary fodder analysis of this sample was, for the dry matter:

	Per cent.
Ash	10.63
Ether extract	2.07
Crude protein	14.18
Crude fiber	30.52
Nitrogen-free extract	42.60
Total	100.00

The average percentage of nitrogen, as determined in the fresh sample, was 2.268, and two years later it was 2.287. There is no apparent change in the nitrogen content caused by its aging.

The co-efficient of digestion, as determined by pepsin solution, was found to be 76.43 per cent., which is rather higher than the maximum for red clover hay, 71, and even higher than that of the green clover, 76. This hay was going on three years old at the time the determination was made.

The amount of xylan found was 16.54 per cent., which is materially more than the maximum found in alfalfa hay. The average nitrogen-free extract in alfalfa hay is close to 32 per cent., while the clover has 43 per cent.; and it seems probable that the excessive xylan found in the clover, owes its origin to the non-fibrous celluloses included in the nitrogen free extract. The fuller analysis of the sample was as follows:

	Per cent.
Invert sugar	1.33
Sugar	0.21
Dextrin	4.03
Starch	0.76
Xylan, inverted by dilute acid	4.03
Xylan, soluble in alkali solution	0.72
Lignones, soluble by chlorin	4.99
Cellulose	18.70
Moisture	5.36
Ash	10.17
Ether extract	1.88
Proteids	13.43
Soluble in alcohol, sugar, etc., deducted Soluble in water, dextrin, etc., deducted	29.59
Not determined	4.80
	100.00

The total loss upon successive extraction with 95 per cent. alcohol, cold water, and then hot water, was 37.8 per cent. The amount extracted from alfalfa hay was, in round numbers, 28 per cent. I did not in this case determine the amount of nitrogen removed by the extractions.

The crude fiber in this case contained 77.88 per cent. cellulose, and 22.12 per cent. of lignones; practically identical with the composition of the crude fiber prepared from alfalfa.

The nitrogen-free extract, however, differs both quantitatively and qualitatively from that of the alfalfa. To what extent this difference is due to the difference in the development of the plants at the time the samples were cut, would be interesting to know. The absence of the sugars in the alfalfa sample and their presence in the clover may be wholly attributable to this. Alfalfa is our principal honey plant and yet this sample which was just coming into bloom yields only traces of the sugars. That they are subquently present cannot be doubted; but whether they are ever present in sufficient quantity to constitute more than a fraction of one per cent. of the hay is a question.

PEA-VINE HAY.

As the quantity of pea-vine hay made in this state aggregates a large amount, I shall, at the risk of digressing too much, give a brief presentation of it in comparison with the other hays, particularly in comparison with alfalfa and clover hays. The variety of pease here dealt with, is what is designated the Mexican pea. It is a strong grower and quite prolific. I am indebted to Mr. James A. Kelley, of Monte Vista, Colorado, for one of the samples of hay and to Mr. R. E. Trimble for the other. Both samples are from the San Luis valley, where the pea-vine hay, to a certain extent, takes the place of alfalfa and clover hay of this portion of the state.

I am informed by Mr. Kelley that experiments in feeding pea-vine hay to horses, steers, and sheep have given very satisfactory results, especially so with sheep. Mr. Kelley's statements of its effects upon horses indicate that they are similar to those of alfalfa, but are much milder and he makes no mention of its producing any cough or the heaves. This hay even when cut, after many of the pease have ripened, is an acceptable fodder to cattle and one on which they do well.

The sample furnished by Mr. Kelley was in perfect condition; the plants were almost at full bloom at the time

of cutting, and the pods had merely formed in the older bloom. The leaves were well preserved. The sample obtained for me, by Mr. Trimble, was of hay cut when the plants were quite mature and a goodly number of the pease were ripe. The hay, however, was in good condition. The samples were ground to a coarse powder, from which smaller samples were prepared for analysis.

COMPOSITION OF PEA-VINE HAY.

Condition at time of Cutting.	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.
Cut at time of full bloom	5.871	11.273	3.200	20.200	29.428	30.028	3.232
Water free	....	11.977	3.398	21.460	31.264	31.901	3.434
Cut when in full pod	6.028	7.135	1.839	16.581	30.013	38.404	2.653
Water free	....	7.592	1.957	17.645	31.938	40.888	2.723

We give, in the subjoined table, analyses of pea-vine ensilage, first cutting alfalfa, and clover hay. The analyses of the ensilage and clover hay are reproduced from Bulletin No. 35.

	Moisture.	Ash.	Ether Extract.	Crude Protein.	Crude Fiber.	Nitrogen-Free Extract.	Total Nitrogen.
Pea-vine ensilage	4.710	14.910	3.240	10.950	30.060	36.130	1.752
Water free	....	15.630	3.400	11.300	31.390	38.540	1.839
Alfalfa, average of first cutting	6.210	10.030	1.550	14.850	36.280	31.080	2.376
Water free	....	10.694	1.653	15.833	38.682	33.138	2.533
Clover hay, water free	....	10.630	2.070	14.180	30.520	42.600	....

The analyses show the pea-vine hay to be richer than either clover or alfalfa in proteids, the alfalfa containing 297 pounds, while the pea-vine hay, cut in full bloom, contains 404 pounds per ton ; and it is only a little higher than the clover hay in crude fiber. We also observe a decrease in the ash constituents and the proteids with the ripening of the plant, so that the pea-vine hay forms no exception to this rule

It will be noticed that it removes a large amount of ash, the hay containing an average of 9.204 per cent. of ash or mineral matter.

These ashes were submitted to analysis and the results are given below, together with an analysis of an alfalfa ash, made from plants of first cutting, full bloom.

The composition of these ashes is as follows:

	Pea Vines in full bloom.	Pea Vines in full pod.	Alfalfa in full bloom.
Carbon	Trace	Trace	0.112
Sand	5.033	4.524	0.829
Silicic acid	2.620	3.293	0.881
Phosphoric acid	6.726	7.070	5.234
Sulphuric acid	4.767	2.620	5.608
Carbonic acid	18.325	21.455	23.730
Chlorin	6.231	3.765	8.500
Calcic oxid	11.614	16.650	27.620
Magnesic oxid	3.669	4.192	3.798
Ferric oxid	0.659	0.560	0.269
Aluminic oxid	0.366	0.548	0.089
Manganic oxid, brown	0.262	0.560	0.168
Potassic oxid, potash	36.164	30.917	24.240
Sodic oxid, soda	1.366	3.629	0.943
Moisture	Not det'd	0.856	0.000
Sum	100.802	100.939	102.021
Less oxygen, equivalent to chlorin	1.188	0.855	1.920
Total	99.614	100.084	100.101

These results show that the pea is a still heavier feeder, particularly upon phosphoric acid and potash, than the alfalfa plant, which, in the aggregate, removes very large quantities of these substances. The phosphoric acid in the alfalfa ash is quite the maximum found in fifteen samples prepared from alfalfa hay, but is less than that in the ashes of the pea vines. On the other hand, the sum of the lime and magnesia in the ashes of the pea vines is only from one-half to two-thirds of the amount found in the various samples of alfalfa ashes. The ashes of the pea vines compare with those of red clover in the same sense and almost in the same degree as with those of the alfalfa. In regard to the total nitrogen in the plant, it will be observed that the pea vines contain materially more of it than alfalfa does. For the purposes of green manuring, they are easily and quickly enough grown to deserve the attention of our ranchmen. They will serve admirably to add organic matter and nitro-

gen to the soil and to render other plant food more available.

CRUDE FIBER AND NITROGEN-FREE EXTRACT.

Our subsequent analyses of these samples, of pea-vine hay, with the object of getting more definite information concerning the composition of the crude fiber and the nitrogen-free extract, resulted as follows:

	In full bloom. Per cent.	In full pod. Per cent.
Invert sugar	0.000	0.000
Cane sugar	0.000	3.050*
Dextrin	0.738	0.705
Starch	0.000	2.530
Xylan, inverted by dilute acid.	3.157	7.237
Xylan, soluble in alkali solut'n	0.816	0.659
Lignones, soluble by chlorin	6.466	10.296
Cellulose	18.646	18.199
Moisture	5.871	6.028
Ash	11.273	7.135
Ether extract	3.200	1.839
Proteids	20.200	16.581
Soluble in alcohol / Soluble in water	28.345	25.841†
Not determined	1.258	.000
	100.000	100.100

I was quite surprised at the absence of starch in the sample in full bloom, but no more so than at the small amount of this substance in the alfalfa and the very small amount in the clover hay. The result for the alfalfa is entirely consonant with the results of the following experiment: A portion of the alfalfa was digested with alcohol and subsequently with cold water, to remove as much of the coloring matter and extractives as possible and then examined under the microscope, at last with the addition of a solution of iodin in potassic iodid, the reaction with the lignocelluloses was very strong, and if there was any reaction for starch it was entirely masked. I at no time succeeding in obtaining a satisfactory test for starch in this manner, though some of the tests might have been interpreted as showing its presence, and I think this interpretation is correct; but it was not clear enough at any time to indicate a large percentage of starch, even after boiling

* A second determination gave 2.94 per cent. † Sugar, dextrin, etc., deducted.

the sample with water. The extract of this sample of pea vines obtained by first boiling it, after having previously freed it from gums and fats, with fifty times its weight of water for an hour and a half, subsequently digesting with diastase for two hours at 55-60 degrees and inverting with 10 c. c. of concentrated hydric chlorid at a temperature of 90-95 degrees, failed to give any more sugar than was added with the diastase though tested three times.

That starch should be found in the other sample is in accord with the condition of the plant at the time of cutting, i. e., in full pod with many ripe pease. The large percentage of lignones in the crude fiber of the hay made from the maturer vines may be due to the relatively large quantity of pods in the sample and suggests a great difference in the quality of the samples.

The pea-vine hay made from the less mature vines resembles the alfalfa samples not only in the amount of lignones present in the crude fiber, but also in the amount of xylan yielded upon distillation, 11.17 per cent. The amount of the lignocelluloses present varies with the maturity of the plant, especially those which are not susceptible to hydrolysis by dilute acids and alkalies increasing with maturity, while the cellulose remains nearly constant.

The furfurol yielding complexes, expressed as xylan, are less abundant in the mature plants than in the younger, but the difference is probably within the limits of error due to the method, and not conclusive as regards their variation in the plant. The sample made from plants in full bloom yielded 11.17 per cent. xylan, and the one cut, when the plants were in full pod, gave 10.23 per cent. The range in the percentage of xylan found in our alfalfa samples is from 8.9 to 14.50 per cent., but fluctuates so irregularly that no evident relation can be discovered between the development of the plant and the amount of xylan found and the same would probably be the case with the pea-vine hay if our series of samples were only slightly extended. It is true, too, that our method is not very sharp and small differences in percentages have so slight a significance that the range of only about six per cent. may be taken as establishing the xylan content of alfalfa and pea-vine hays at about ten or twelve per cent. The relation of the lignones to the xylan found is not made apparent by our results, if any exists at all; the ratios obtained are approximately as follows: for clover, 0.30:1; for alfalfa, 0.47:1; for pea-vine hay, cut when the plants were in full bloom, 0.42:1; but for pea-vine hay cut when the plants were in seed, the ratio found

is 1:1. There is evidently no approximation to a uniform ratio shown by these figures.

The residue obtained from the mature sample by successive extractions with alcohol and cold water yielded, upon distillation with hydric chlorid, xylan equivalent to 8.01 per cent. of the air dried hay, or 78.2 per cent. of the total xylan. This seems to indicate a greater difference between the pea-vine hays, in regard to the character of the lignocelluloses present, than in regard to the other constituents. The deportment of the hay from the vines in pod toward heat, i. e., the readiness with which it browns, is probably due to the large amount of these lignocelluloses present. I have not observed so great a sensitivness in any sample of fodder which I have analyzed. The roots of alfalfa alone have exceded it in this respect.

Accepting the phloroglucin reaction as indicative of the amount of these lignocelluloses, I began a series of observations on samples of alfalfa taken from the same root, at intervals of seven days, the first sample being taken when the stems were only four or five inches high. The intention was to continue the taking of samples from this plant at the stated intervals until the plant was fully ripe, and to study the development of the lignocelluloses in thin sections under the microscope for each internode of stems throughout the whole period of growth. An accident to my chosen plant, it having been cut up, brought this experiment to a sudden end. My observations indicated the absence of these in the very young joints, and their subsequent development in two rings, the first continuous with the fibrovascular ring whose outer margin was fluted, while the second one lay outside of this and was composed of individual bundles, sometimes, but not always, coalescing so that the ring was broken.

The co-efficient of digestion of the proteids in these pea-vine hays, as determined by artificial digestion, are rather higher than, but not very different from, those found for the proteids in alfalfa hay. They are, for the pea-vine hay, cut when the plants were in full bloom, 84.71; and, cut when the plants were in full pod, 81.61.

I can not find that the co-efficient of digestion of such hay has been determined by experiments with animals, though such experiments have been made with pea straw, the proteids of which have a digestion co-efficient of 61; also with pease in which the co-efficient is, for ruminants, 89; for horses, 86; and for swine, 88, from which it would appear that the proteids in such pea-vine hays are of nearly

as much value as the proteids in the pease themselves. In this statement, the amount of amids which may be present in the pea vine is not considered.

The crude fiber of the pea-vine hay, sample in full bloom, was composed of 74.25 per cent. of cellulose, and 25.75 per cent. of lignones. This is quite close to the composition of the crude fiber from the alfalfa and clover hays in which the cellulose was 79.96 and 77.88 respectively.

Whatever the value of the lignones may be, this seems to be true of these three leguminous hays, cut when the plants are in full bloom or earlier, i. e., that there is about six or seven per cent. of them present which resist the action of dilute acids and alkalies, even when the soluble portions of the hay have been removed by previous extractions with alcohol and water. In the sample of pea-vine hay in pod these lignones increased and the cellulose in the crude fiber amounted to 63.82 per cent. I have already suggested the presence of a large percentage of pods as a possible explanation. This, however, only means a particular stage in the development of the plant.

UPLAND AND MEADOW HAY.

These names are applied to hay made from grasses growing for the most part on level grounds along streams or where water courses have been.

The grasses making up this class of hay are numerous. Prof. C. S. Crandall, of the Department of Botany, kindly determined those present in the sample analyzed. The first two in the list made up the major portion of the sample. They were as follows: *Andropogon scoparius, Mich.*; *Carex marcida, Booth.*; *Elymus canadensis, L.*; *Panicum virgatum, L.*; *Sporobolus asperifolius, Thurb.*; *Sporobolus cryptandrus, Gray*; *Poa tennifolia, var. rigida, Vasey*; *Andropogon furcatus, Muhl.*; *Chrysopogon avenacrus, Benth.*; *Calamovilfa longifolia, Hack.*; *Agropyrum tenerum, Vasey*; *Bouteloua oligostachya, Torr.*

This hay was made in the latter part of August, 1896; it was cut from land belonging to Mr. J. J. Ryan, and lying close to the Big Thompson river, near the town of Loveland, this county.

This hay was considered to be a good quality of this class which is in large demand, at all seasons. The market value of such hay is always greatly in excess of that of alfalfa, usually a little less than twice that of alfalfa hay, and often fully twice. I am, myself, not in position to express an opinion as to what extent this difference in price is due to the differeace in the supply of the respective hays, but

persons who keep horses for road purposes, liverymen and others, will not use alfalfa hay. On the other hand, feeders of cattle and sheep use alfalfa principally, if not exclusively, in this section. I do not know how this matter stands relative to pea-vine hay, but the pea-vine silage has been fed with very satisfactory results.

It would seem that the low esteem in which alfalfa is held as feed for horses, is mostly due to its action upon the kidneys and bowels of the animal and also to the fact that the loss in feeding horses alfalfa hay is very large, due to their not eating the leaves readily, and lastly, because the alfalfa is sometimes dusty. It may be that this is in part a practical recognition of the fact that the nutritive ratio of the whole hay is rather a narrower one than is desirable. Be this as it may, an average alfalfa hay has a much larger percentage of proteids than the upland hay, also less crude fiber, and the proteids in the alfalfa have a higher co-efficient of digestion. The same is in a measure true of clover hay, but the upland hay is preferred for feeding animals at work.

The composition of the upland hay was as follows:

	Per cent.
Moisture	3.047
Ash	7.886
Ether extract	2.219
Proteids	6.131
Crude fiber	40.372
Nitrogen-free extract	40.351
Total	100.000

The co-efficient of digestion for the proteids found by artificial digestion was 45.77, about equal to that given for the proteids in late cut timothy. I gave on a preceding page an analysis of hay made from Stipa viridula, in comparison with an analysis of a mixed hay. In that analysis the proteids are given as 8.91 per cent. We see that it is richer also in this constituent than our native hays, which are in great demand at all times. Not only is the amount of the proteids larger in the Stipa, but their co-efficient of digestibility is also higher, being 64.71. It would have been interesting to have studied the Stipa hay still further to see if we could solve the question why this grass is not eaten, but we were compelled to drop the comparative study at this point, and all that we are justified in stating is that, in spite of the fact that cattle do not eat it, it has, according to

analysis, the composition of a good fodder, better in some respects than mixed hay, and that the co-efficient of digestion for its proteids is higher than that of our native hay, which is considered a very desirable one.

The native hay yields, when analyzed according to our method, exceedingly different results from the leguminous hays.

While the following analysis may not be so exact as one might wish, it is not far from the truth, and shows that there is a very great difference between the two classes of hay—hay made from leguminous plants and hay made from the grasses. Subsequent investigation may, it is true, modify these results somewhat, but we think that this difference exists and that it is fully as great as appears from the results of our analysis. I know of no analysis of hay made in a similar manner; a single determination of sugar—sucrose—in a sample of timothy hay, by Professor Stone, is all that I can find. He gives the sugar in his sample of timothy hay as 2.53 per cent.

ANALYSIS OF UPLAND HAY.

	Per cent.
Invert sugar	0.00
Cane sugar	0.98
Dextrin	0.00
Starch	0.40
Xylan, inverted by dilute acid	1.77
Xylan, soluble in dilute alkali	0.79
Lignones, dissolved by chlorin	3.12
Cellulose	27.93
Moisture	3.05
Ash	7.89
Ether extract	2.22
Proteids	6.13
Soluble in alcohol, sugar, etc., deducted / Soluble in water, dextrine, etc., deducted	19.75
Not determined	35.97
	100.00

The reaction of the original sample and also the crude fiber prepared from it with phloroglucin is very much fainter than that given by the leguminous hays. I regret that we did not determine the total xylan by distillation, as that might have added something to our knowledge of the thirty-six per cent. which is missing. But the comparative faintness of the phloroglucin reaction indicates that the

pentaglucoses are not present to the same extent as in the alfalfa and other leguminous hays.

In the usual fodder analysis the two most striking points are the high percentages of crude fiber and nitrogen-free extract. In the second analysis the most remarkable percentages given are for the cellulose and those things embraced under the term "not determined," which includes substances soluble in dilute acid and dilute alkali, but insoluble in alcohol and water. The portion soluble in alcohol and water is low and a large portion of the 40.3 per cent. nitrogen-free extract is included in the 36 per cent. "not determined."

In order that the comparison of these analyses may be facilitated, we bring them together in the following table:

	Alfalfa Hay, coming in bloom.	Clover Hay Heads, half turned.	Pea-vine Hay in full bloom.	Pea-vine Hay in full pod.	Upland Hay.
Invert sugar	0.00	1.33	0.00	0.00	0.00
Cane sugar	Trace	0.21	0.00	3.05	0.98
Dextrin	Trace	4.03	0.74	0.71	0.00
Starch	1.11	0.76	0.00	2.53	0.40
Xylan, by acid	3.76	4.03	3.16	7.24	1.77
Xylan, by alkali	0.15	0.72	0.82	0.66	0.79
Lignones	6.66	4.99	6.47	10 30	3.12
Cellulose	25.59	18.70	18.65	18.20	27.93
Soluble in alcohol, sugar, etc., dedutced	13.87	29.59	28.35	25.84	19.75
Soluble in water, dextrin, etc., deducted	11.88				
Moisture	7.21	5.36	5.87	6.03	8.05
Ash	9.81	10.17	11.27	7.14	7.89
Ether extract	1.15	1.88	3.20	1.84	2.22
Proteids	15.16	13.43	20.20	16.58	6.13
Not determined	3.65	4.80	1.25	0.00	35.97
	100.00	100.00	100.00	100.10	100.00
Co-efficient of digestion for the proteids	79.15	76.43	84.71	81.61	45.77

This shows the pea-vine hay to contain the largest percentage of proteids, with the highest co-efficient of digestion, with the alfalfa next in both respects. The pea-vine hay has the lowest percentage of cellulose and the upland hay the highest; in this respect the pea-vine and clover hays stand quite apart from both the alfalfa and upland hays. The

sugars and starch, which we have for the most part understood by carbohydrates, are present in small quantities. The sample showing starch to be present in the largest quantity contained some mature seeds, which contain from 48 to 50 per cent. of starch. The sugar found in the same sample may be correct, but I think it admits of a doubt.

CONCLUSIONS.

First.—That the composition of alfalfa hay grown under the same climatic conditions does not vary from year to year, more than samples of the same year, which is within fairly narrow limits.

Second.—That climatic or seasonal differences do affect the composition of the hay. This, however, affects the different cuttings of the same year, rather than the crops for a whole year, but this effect is comparatively small and expresses itself most pronouncedly in the percentage of crude fiber.

Third.—That the amount of the proteids in alfalfa hay does not decrease with, but rather increases, with age, if the hay is kept in a close mow.

Fourth.—That the changes in the hay probably affect the amount and character of the nitrogen-free extract.

Fifth.—That the proteids of the different cuttings are about equally digestible, as determined by means of pepsin-hydrochloric acid. There is, however, a slight difference in favor of the hay cut when the plants were in full bloom.

Sixth.—The digestibility of the proteids does not vary materially from year to year, nor is it affected by the age of the hay, if well kept.

Seventh.—That the lignocelluloses in alfalfa increase with the age of the plant, but there are exceptions which can not be justly attributed to methods of determination.

Eighth.—That the presence and amount of sugar,starch, etc. depend upon the development of the plant at the time of cutting, and is at all times comparatively small.

Ninth.—That the lignocelluloses are more abundant in the leguminous hays than in those made from our native grasses, but that the cellulose is much more abundant in the latter.

Tenth.—That the soluble portion of leguminous hay, is greater than that of the little hay made from the grasses which accounts for their susceptibility to weathering

THE STATE AGRICULTURAL COLLEGE

THE AGRICULTURAL EXPERIMENT STATION

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BARLEY

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ALSTON ELLIS, PRESIDENT

FORT COLLINS, COLORADO

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BARLEY.

BY W. W. COOKE.

The barley plant is not properly appreciated in Colorado. There are but about 15,000 acres grown in the State, and they are credited with producing, in 1896, 450,000 bushels or 21,600,000 pounds of barley, an average of 30 bushels or 1,440 pounds per acre.

This yield compares well in value with the returns made by wheat the same year. There is quite a general belief that barley does not do well in Colorado, and this deters many from giving it a fair trial. Barley has been grown on the College Farm for many years, and all of the common varieties have been tested for longer or shorter periods. The yields have always been satisfactory, and during the later years have been highly successful. When these results are considered in connection with the fact that the College farm is by nature, both in the lay of the land and the character of the soil, below the average, it is fair to presume that, if properly handled, barley will give bounteous yields on other farms of the State.

One of the commonest mistakes in raising barley, is not to give it water enough. Barley will grow and make a crop on a small amount of water. Even at Fort Collins, which is in the arid region, a crop of barley can be raised one year in three, without irrigation. Because of these facts, farmers are inclined to slight the crop, and when water is short, give it to the other crops. Another peculiarity of barley is, that it does not show to the eye the need of water, until it has suffered beyond redemption. When barley grows with a shortage of water, it retains its natural color, but fails to grow long straws and stools but little. It throws all its strength into forming the heads, and these begin to show at scarcely eight inches above the ground. Water applied at this stage, will carry these heads on to ripeness, but will not produce much more growth of straw, no more stooling, and the heads will have but few kernels.

Barley prefers an open, warm soil, tending to clay rather than sand, with good drainage and not much alkali. It does better on rich land, and thrives well on land the first year after treating with stable manure. But, of course, in this latter case, it requires much more care in the irrigating and considerably more water. When well fed and watered, the growth is enormous and the probability is, that some of it will lodge. Our experience on the College Farm is, that lodging does but little damage. The heaviest yields we have ever secured have been from fields that were badly lodged. One in particular, lodged quite badly and went down flat. But the last few inches of the stalk turned up enough to keep the head off of the ground, and, though hard to cut and bind, the grains were plump, well filled out, and the yield enormous.

The treatment of the subject of barley in the following pages will be from the standpoint of the feeder. Colorado can grow first-class malting barley, can obtain as many bushels per acre as Iowa or any other of the barley growing states, and usually has dry weather at the time of barley harvest, so that the crop is secured without discoloration and in the best condition for use. There is a moderate local demand for malting barley, and, up to the point where this demand is supplied, barley is a more profitable crop than wheat.

There is, however, almost an unlimited demand for barley as a stock feed, to take the place of part of the corn that is now imported from Kansas and Nebraska.

It is with reference to its growth for this purpose, and the methods and results of feeding it to stock, that the remainder of this bulletin will be devoted.

VARIETIES.

The barleys can be separated into two classes: the common hulled varieties and the hulless, or naked varieties. These latter are often called "bald barley." The common hulled varieties are well known everywhere. The hulless varieties have no beards; they lose the hull in threshing, the same as wheat, and the cleaned grain closely resembles wheat; but the sides are more rounded and the upper end more pointed.

The common barleys can be divided into malting and non-malting, while the principal varieties of the hulless are the black and white.

The hulless barleys are not much raised in Colorado, but within the past few years, one variety known as the "Success" barley, has gained a good reputation as a profitable crop in the foothills and mountain parks from 7,000 to 8,500 feet altitude. At 7,000 it matures a crop of grain. Up to 8,500 feet it will make a heavy crop of hay, if cut just after blossoming, that takes the place of both hay and grain. Many teams do heavy work, in lumbering all winter long, with nothing to eat but this barley hay.

On the plains, under irrigation, some varieties of the common barley give so much larger yields than the hulless that the latter is not much grown. It is probable that even there the hulless barley could be grown at a profit, mixed with oats as a stock food. When sown together at the rate of thirty pounds of hulless barley and seventy-five pounds of oats per acre, the barley seems at first the leading crop. It shoots up above the oats, soon heads out and has the appearance of a barley

crop. The heads ripen and turn downward, while the straw remains upright. Later the oats shoot far above the barley and make a crop that is apparently not lessened by the presence of the barley. The double crop is harvested when the oats are fully matured. A large field grown to hulless barley in 1893 and sown to oats in 1894 without additional seeding of barley, yielded 48 bushels per acre of the mixed grain, weighing 47 pounds per bushel or 2,256 pounds of grain per acre. Treated in this way, some of the barley shells out and reseeds the ground. These grains live over winter, and, if the land is to be kept in oats for several years in succession, once seeding with barley is sufficient. On account of this fact, wheat should never be grown after hulless barley, if it is expected to use the wheat for flour. Hulless barley can be gotten rid of by planting the land to a hoed crop or to alfalfa. The seeds of hulless barley are so heavy that they do not spread in ditch water as do those of wild oats.

TESTS OF VARIETIES.

TESTS OF 1887.

Small plots, hand-planted, selected seed, in drills 22 inches apart, four pounds of seed per acre.

Name of Variety.	Per cent of seed germinating.	Yield of grain per acre in bushels.	Number of days ripening.
Smooth Hulless	84	30	114
Winnepeg No. 1	83	35	114
Winnepeg No. 2	80	35	123
New Zealand	82	35	121
Chevalier	84	55	112
Zealand	84	47½	112
Winter 6-rowed	73	62½	126
Purple	72	37½	116
Melon	99	40	117
Del Norte	76	47½	116
Triumph	67	47½	116
India	88	47½	116
Kilima	93	50	117
Scotch Amat	93	35	116
Black	96	60	116
Palestine	71	37½	117
Amat	93	35	127
Guy Malye	82	47¼	116
Manchurian	66	37½	
Frick's	79	50	
Spring 4-rowed	75	47½	
Erfurt	93	47½	
Nepaul	79	47½	
Winter 4-rowed	76	47½	
Phœnix	77	47½	
Sibley's Improved	78	55	
Manshury	72	50	
Adams's Heavy	94	55	
Sibley's Pearl	92	27½	
Sibley's Purple	95	50	
Battledore	76	35	

TESTS OF 1888.

Small plots, selected seeds, 7 pounds per acre, hand planted in drills 13 inches apart.

Name of Variety.	Per cent of seed germinating.	Yield of grain per acre in bushels.	Yield of straw per acre in pounds.	Number of days ripening.
Smooth Hulless	90	25	720	89
Winnipeg No. 1	94	18.3	1040	89
Winnipeg No. 2	90	21.7	96	90
New Zealand	97	28.3	880	89
Chevalier	90	25	1360	94
Zealand	94	31.7	880	90
Winter 6-rowed	92	18.8	640	97
Purple	84	33.3	800	90
Melon	100	19	1120	92
Del Norte	94	33.3	1760	90
Triumph	81	33.3	120	92
Indian No. 4	92	28.3	1280	92
Kilma	97	33.3	1200	90
Scotch Amat	97	33.3	912	90
Black	95	33.3	1040	90
Palestine	91	26.6	1200	92
Animate	93	31.7	896	92
Guy Malye	94	36.6	960	90
Manchurian	96	18.5	800	90
Frick's	97	33.3	1280	90
Spring 4-rowed	92	19	1360	90
Erfurt	90	28.3	1120	92
Nepaul	83	26.6	104	90
Winter 4-rowed	95	18.6	904	90
Phœnix	94	18.3	960	92
Sibley's Improved	91	18.5	1280	90
Manshury	96	18.8	104	90
Adams's Heavy	95	31.7	1040	92
Sibley's Pearl	98	35	1520	92
Sibley's Purple	94	18.6	880	97
Wales	94	18.3	1440	107
Berkley	94	2.3	88	90
Zeochrit	79	28.3	912	100
Perlgerste	84	2.3	880	112

TESTS OF 1889.

San Luis Valley Sub-Station.

Small plots, 50 pounds of seed per acre, in drills six inches apart, sown with a hand drill.

Name of Variety.	Length of straw in inches.	Date of ripening.	Number of days ripening.	Yield of grain per acre in bushels.
Black	22	August 22	114	16.3
Hulless	20	" 22	114	10.2
Nepaul	22	" 22	114	14.9
Melon	23	" 30	122	21.1
Phœnix	21	" 22	114	14.6

Arkansas Valley Sub-Station.

Small plots, 26 pounds of seed per acre, in drills 18 inches apart, sown with hand drill.

Name of Variety.	Number of days ripening.	Yield of grain per acre in bushels.
Black	91	16.2
Hulless	91	15.7
Melon	91	18.5
Phœnix	91	14.8

TESTS OF 1890.

Drilled.

Small plots, 5 pounds of seed per acre, in drills 18 inches apart, sown with a hand drill. Sown March 28.

Name of Variety.	Date of cutting.	Height in inches.	Yield of grain per acre in bu.
Smooth Hulless	July 22	34	38.5
Winnipeg	" 22	32	37
Winter 6-rowed	" 25	28	30.1
Purple	" 21	35	41
Guy Malye	" 21	31	55.6
Frick's	" 22	37	30.1
Berkley	" 22	35	38.1
Unknown	" 25	32	21
Unknown	" 26	32	21.6
Algerian No. 1		29	22.6
Algerian No. 2	" 23	24	13.1
Algerian No. 3	" 23	30	33.1

Hand Planted.

Small plots, one seed each six inches, in drills 18 inches apart or about 5 pounds of seed per acre. Sown March 28.

Name of Variety.	Date of cutting.	Height in inches	Yield of grain per acre in bu.
Smooth Hulless	July 24	31	32.6
Winnipeg	" 23	29	31.1
Winter 6-rowed		23	27.6
Purple	" 23	31	26.1
Guy Malye	" 23	31	29.5
Frick's	" 24	35	25.6
Berkley	" 26	34	17.1
Unknown	" 26	32	19.1
Unknown	" 28	32	20.1
Algerian No. 1	" 26	28	22.6
Algerian No. 2	" 26	24	23.1
Algerian No. 3	" 26	29	30.1

Arkansas Valley Sub-Station.

Small plots, 26 pounds of seed per acre, in drills 18 inches apart, sown with hand drill. Sown April 22.

Name of Variety.	Number of days ripening.	Yield of grain per acre in bushels.
Black	84	31.4
Hulless	84	30.3
Melon	84	30.1
Phœnix	84	21.5

TESTS OF 1891.

Field plots, 90 pounds of seed per acre, sown with machine drill. Sown April 27.

Name of Variety.	Date harvested.	No. of days ripening.	Yield of grain per acre in bu.
Purple	July 22	86	42
Guy Malye	" 20	84	54
Palestine	" 25	89	40.5
Frick's	" 28	92	44
Smooth Hulless	" 28	92	41.8
Winnipeg No. 1	" 21	85	44.5
Algerian No. 3	" 30	97	57.5

TESTS OF 1892.

Field plots, 90 pounds of seed per acre, sown with machine drill.

Name of Variety.	Date of harvesting.	Yield of grain per acre in bushels.
Purple	July 28	20
Guy Malye	" 29	30
Smooth Hulless	August 2	25
Frick's	" 8	30
Smooth Hulless	" 2	40
Winnipeg	" 8	33.3
Sonora	" 2	9.5

San Luis Valley Sub-Station.

Planting the same as above.

Guy Malye	August 1	24.2
Frick's	" 26	28
Palestine	" 26	28
Sonora	September 10	11

TESTS OF 1893.

Field plots, 90 pounds of seed per acre, sown with machine drill.

Name of Variety.	Date of planting.	Date of harvesting.	Yield of grain per acre in bu.
Guy Malye	May 15	August 8	24
Success	" 11	" 8	21

TESTS OF 1894.

Field plots, 90 pounds of seed per acre, sown with machine drill.

Name of Variety.	Yield of grain per acre in bushels.
Champion	51
Nepaul	27
Black	24
Manshury	34
New Zealand	51
California	50
Italie	23
Celeste Petite	23

TESTS OF 1895.

Field plots, 90 pounds of seed per acre sown with machine drill.

Name of Variety.	Date of planting.	Date of harvesting.	Yield of grain per acre in bu.
New Zealand	April 3	July 31	22.5
Black	" 3	" 28	25.6
California (Volunteer)		August 1	49
California	" 4	" 1	83
Chevalier	" 4	" 8	79

TESTS OF 1896.

Field plots, 90 pounds of seed per acre, sown with machine drill.

Name of Variety.	Date of planting.	Date of harvesting.	Yield of grain per acre in bu.
California	April 7	July 21	33.8

From the above records it will be seen that many varieties of barley have been grown on the College Farm and Sub-Stations for several years. For the past three years, a large number of varieties of foreign barleys have been grown on small plats, but as none of them have seemed to be an improvement on the kinds usually grown, their records are not here given.

Without going into any extended discussion of the merits of the different varieties, it may be said in general, that the white varieties of hulless barley have usually produced better than the black or purple, though some individual yields of small plats of the purple have been very high. It should be remembered in comparing the yields of the common and the hulless barleys, that the latter weighs fully sixty pounds to the bushel, and hence represents a quarter more value per bushel than the hulled varieties.

Among malting varieties the Chevalier has given by far the best results. It is, however, to the results obtained with common barley for feeding purposes that special attention is desired. The California has given the largest yields and we have finally settled on it as being the best for raising for sheep feeding. This variety has been tested at the Home Station at Fort Collins, and at the Sub-Stations at Cheyenne Wells, Rocky Ford, and Monte Vista. At Cheyenne Wells it was the only cereal that withstood the severe drouth of 1895. At Rocky Ford it produced 200 bushels from a field of five acres, in spite of a hard hailstorm, while even at the high altitude of the San Luis Valley, at Monte Vista, it produced 38 bushels per acre on a large field.

Its record at Fort Collins has already been given. In 1896, with but one light irrigation, it yielded 33.8 bushels per acre. In 1894, the yield was 50 bushels per acre with a fair season, and not much shortage of water. The banner year was 1895. That season the barley was put on a piece of bottom land that had been drained and cultivated for several years until it showed signs of impoverishment. It was covered with a very heavy coat of stable manure during the winter of 1893-4. The summer of 1894, it was planted to corn and in 1895 to barley. The growth of straw was enormous and the heading out perfect. Although lodged flat by a hard wind, it ripened its crop. From this field of about three acres, there were gathered by the self-binder, 83 bushels per acre, of well cleaned, solid grain. A few days later when the straw had somewhat straightened, it was cut close to the ground with a mower, and produced two large loads of straw that was thrown to the hogs, and contained grain enough to give them full feed for about three weeks. A heavy crop of volunteer barley showed that much had shattered out in addition to the enormous quantity gathered.

The same year this variety was sown on more than twenty farms between Fort Collins and Greeley. The results were uniformly satisfactory, the yields ranging from 50 to 80 bushels to the acre.

FEEDING VALUE OF BARLEY.

The value of any material as a food can be tested in two ways: first, by submitting it to chemical analysis to ascertain the amount of food constituents it contains; second, by feeding it to stock and noting the results. Our study of barley includes both of these methods.

The method by chemical analysis is the easier and quicker, but it is not certain yet that we know how to interpret the figures obtained by the analysis. The work has been confined to two representative varieties: the California as the best of the non-malting common barleys, and the Smooth Hulless as representing the bald barleys. For the remainder of this bulletin the terms "common barley" and "bald barley" will be understood as referring to these varieties. Both kinds were analyzed and the analyses are given herewith, in comparison with those of corn, wheat, oats, and bran, since these are the feeds with which barley comes most in competition. The analyses are of the material in the air dry condition in which it is usually fed.

	Water	Ash	Crude Protein	Fat	Nitrogen Free Extract.	Crude Fiber.
Common Barley*	10.09	1.87	8.66	2.47	73.82	3.09
Bald Barley*	9.44	3.34	13.21	2.69	68.55	2.77
Wheat	10.52	1.83	11.87	2.09	71.90	1.79
Corn	10.56	1.53	10.25	5.02	70.40	2.24
Oats	10.98	2.98	11.80	4.96	59.74	9.54
Bran	11.91	5.78	15.42	4.03	53.87	8.99
Common Barley†	10.80	2.44	10.69	2.13	69.89	4.05
Bald Barley†	10.00	2.44	11.97	2.50	70.08	2.83

*Used in the feeding experiments.

†Average composition as given in the reports of the United States Department of Agriculture.

The preceding figures show the amount of each material contained in a hundred pounds of the grain. Some of this is digestible and useful to the animal. Much of it is indigestible and worthless.

The next table gives the per cent. of each of these that is commonly considered as digestible.

	Crude Protein.	Fat.	Nitrogen Free Extract.	Crude Fiber.
Common Barley	75	74	90	34
Wheat	71	84	93	25
Corn	72	74	93	37
Oats	81	82	73	23
Bran	79	71	73	25

No figures are given in the above for bald barley. So far as the present writer is aware, no digestion experiments have been made with this grain. From its nature, it is fair to presume that it would be about as digestible as wheat, and the figures for wheat have been used in making the calculations of the following table.

	Digestible Protein.	Digestible Fat.	Digestible Nitrogen Free Extract.	Digestible Fiber.	Total Digestible Material.
Common Barley*	6.50	1.85	66.44	1.03	75.82
Bald Barley*	9.38	2.24	63.70	0.69	76.01
Wheat	8.43	1.76	66.87	0.45	77.51
Corn	7.38	3.71	65.47	0.83	77.39
Oats	9.56	4.08	43.61	2.19	59.44
Bran	12.18	2.86	39.32	2.25	56.61
Common Barley†	8.02	1.58	62.90	1.38	73.88
Bald Barley†	8.50	2.10	65.17	0.71	76.48

*Used in the feeding experiments. †Average composition.

This last table is obtained by combining the other two. Thus the first table gives a hundred pounds of common barley as containing 8.66 pounds of crude protein; the second table says that 75 per cent. of this is digestible. Hence 100 pounds of common barley contain 6.50 pounds of digestible protein.

In the tables given above the figures 75 and 71 were used to represent the per cent. of digestibility of the protein in the common and bald barleys. The Chemist of the Station who made the analyses of the barley already given, also made a special test of artificial digestion on both the barleys by the method already published in Bulletin No. 39, of this Station. The results are 77 per cent. for the common barley, and 75 per cent. for the bald barley.

Among feeding materials of the same general character, it is believed that the total digestible material offers a pretty fair measure of their comparative feeding value. From this standpoint it will be seen that barley belongs to the more highly concentrated and digestible grains, like wheat and corn, rather than the lighter feeds, oats and bran.

There is no great difference in the chemical composition or the digestibility of wheat, corn, and barley. Judged from the standpoint of the chemist, they have almost exactly the same feeding value.

FEEDING TESTS WITH BARLEY.

Barley has been fed experimentally on the College Farm to steers, sheep, and pigs. Most of the tests have been with the common barley, but during 1896–'97 the bald barley was extensively fed. The tests were designed to answer the following questions:—

1. How does common barley compare as a stock food, with wheat and corn?

2. Is it better to feed barley alone or with corn?

3. How does bald barley compare in feeding value with common barley and with corn?

4. Is anything gained by grinding either common or bald barley for feeding to stock?

The tests cover a period of three years and will first be given separately for each class of animals, and then a summary presented of the results

FEEDING TESTS WITH PIGS.

First Test. Fall Pigs of 1894.

There were eleven pigs in the test. Six pigs were put in a large pen and fed ground common barley. The other five were put in a similar pen and fed whole corn. The pens were not fed the same amount of grain, but each was fed all that would be eaten up clean.

Feed.	Average Weight at Beginning of Test.	Average Weight at End of Test.	Average Gain in Weight.	Grain eaten per Pig.	Grain eaten for each pound of Growth.
Barley	152	240	88	481	5.4
Corn	159	235	7	430	5.6

The results are slightly in favor of barley. The pigs getting barley, eat more grain and grow faster and require a trifle less grain to produce a pound of growth.

Second Test With Pigs. Spring Pigs of 1895.

A repetition of the preceding test with the same number of pigs, divided and fed in the same manner, but the pigs are smaller and younger at the beginning of the test.

Feed.	Average Weight at Beginning of Test.	Average Weight at End of Test.	Average Gain in Weight.	Grain eaten per Pig.	Grain eaten for each pound of Growth.
Barley	89	194	105	452	4.3
Corn	101	214	113	480	4.3

The results of the second test are just the reverse of the first, i. e., the pigs getting corn eat a little more grain per head and grow a little faster—just fast enough to balance the extra grain; so that the same amount of grain is eaten by each lot per pound of growth. Combining the figures of the two tests there is a substantial equivalence of the results, the pigs eating the same

amount, growing at the same rate, and eating the same quantity of grain for each pound of growth. Thus, under the conditions of these experiments, barley and corn have shown equal feeding value.

One noteworthy feature of the two tests is, the smaller amount of grain the younger pigs required to make a pound of growth as compared with the other pigs. This difference would amount to half a cent a pound in the cost of raising the pork.

Third Test with Pigs. Winter of 1896-'97.

From November, 1896, to April, 1897, an extensive series of feeding tests was made with forty-four pigs divided into nine groups. The rate of growth, as will be seen from the results, is rather small and is due to the fact that the feeding was done in an open shed where the temperature was below freezing most of the time, and often below zero. As the conditions were the same for all the pigs, this does not affect the reliability of the comparisons and conclusions.

The feeds tested were corn, bald barley, and common barley, each fed whole and also ground; each fed with and without skimmilk. Each test was continued for about six weeks. There were several re-arrangements of the pigs, so as to make the conditions of each comparison as nearly equal as possible.

FEEDING RECORDS. WINTER OF 1896-'97.

Period.	Number of Pigs.	Average Weight at Beginning of Test.	Average Weight at End of Test.	Average Gain in Weight.	Average Daily Gain in Weight.	Average Daily Feed. Grain lbs.	Average Daily Feed. Skim-milk qts.	Food per lb. of Growth. Grain lbs.	Food per lb. of Growth. Skim-milk qts.
WHOLE CORN.									
1	5	25	30	5	0.10	1.2		11.8	
2	5	76	86	10	0.27	1.8		6.8	
3	5	77	91	14	0.33	2.2		6.7	
4	5	117	125	8	0.27	2.9		10.7	
GROUND CORN.									
1	5	32	44	12	0.24	1.8		6.6	
3	4	76	90	14	0.33	2.7		8	
4	5	92	104	12	0.40	2.9		7.3	
WHOLE CORN AND SKIMMILK.									
2	5	46	77	31	0.84	1.8	3	2.1	3.5
3	5	86	119	23	0.55	2.3	1.9	4.1	3.4
GROUND CORN AND SKIMMILK.									
2	4	42	76	34	0.92	1.8	3	2	3.3
4	5	57	84	27	0.90	2.7	2	3	2
WHOLE BALD BARLEY.									
1	5	30	46	16	0.32	1.6		5.0	
1	5	68	93	25	0.50	2.2		4.4	
2	4	106	116	10	0.27	1.8		6.8	
2	5	59	73	14	0.40	1.8		4.8	
4	4	186	199	13	0.43	3.7		8.5	
GROUND BALD BARLEY.									
1	5	31	50	19	0.38	1.6		4.3	
2	4	63	85	22	0.60	1.8		3.1	
4	5	92	110	18	0.60	2.9		4.9	

Period.	Number of Pigs.	Average Weight at Beginning of Test.	Average Weight at End of Test.	Average Gain in Weight.	Average Daily Gain in Weight.	Average Daily Feed. Grain lbs.	Average Daily Feed. Skim-milk qts.	Food per lb. of Growth. Grain lbs.	Food per lb. of Growth. Skim-milk qts.
WHOLE BALD BARLEY AND SKIMMILK.									
1	4	70	131	61	1.22	2.3	6.0	1.8	5.0
3	4	116	150	34	0.80	2.6	2.4	3.5	3.0
3	5	73	101	28	0.67	2.3	1.2	3.4	2.2
GROUND BALD BARLEY AND SKIMMILK,									
3	3	70	116	46	1.10	2.8	2.0	2.6	2.0
4	5	77	107	30	1.00	2.9	2.0	3.0	2.0
WHOLE COMMON BARLEY.									
1	5	30	44	14	0.28	1.6		5.7	
3	5	63	75	12	0.29	2.3		7.8	
4	4	144	162	18	0.60	3.6		6.0	
GROUND COMMON BARLEY.									
1	5	27	40	13	0.26	1.6		6.2	
3	5	65	82	17	1.40	2.3		5.6	
WHOLE COMMON BARLEY AND SKIMMILK.									
2	5	35	63	28	0.76	1.7	2.1	2.2	2.8
GROUND COMMON BARLEY AND SKIMMILK.									
2	5	37	65	28	0.76	1.7	2.1	2.2	2.8
4	3	59	100	41	1.37	4.2	2.3	3.1	1.7
GROUND COMMON BARLEY AND GROUND CORN.									
1	5	26	39	13	0.26	1.6		6.1	
2	5	41	51	10	0.24	1.7		6.1	
GROUND COMMON BARLEY, GROUND CORN AND SKIMMILK.									
3	5	51	88	37	0.90	2.3	1.9	2.6	2.1
4	5	83	133	50	1.67	2.9	2.0	2.9	2.0

Average Results of the Different Feeds.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per pound of Growth.	
				Grain lbs.	Skim-milk qts.	Grain lbs.	Skim-milk qts.
Whole Corn	6	71	0.39	2.0	0,7	7.0	1.1
Ground Corn	5	60	0.46	2.4	1.0	5.4	1.1
Whole Bald Barley	8	88	0.58	2.3	1.2	5.0	1.3
Ground Bald Barley	5	67	0.74	2.4	0.8	3.6	0.8
Whole Common Barley	4	68	0.49	2.3	0.5	5.4	0.7
Ground Common Barley	4	47	0.70	2.4	1.1	4.3	1.1
Ground Corn and Barley	4	50	0.77	2.1	1.0	4.1	0.8

VALUE OF GRINDING GRAIN FOR PIGS.

The preceding tests offer thirteen comparisons of whole and ground grain. In almost every case, the ground grain has given decidedly better results than the unground. This is most noticeable in the case of corn. The little pigs weighing only 25 pounds each, made but small headway eating whole corn, and gained but the tenth of a pound per day per head. The older pigs had no trouble in masticating the grain, but their growth is still somewhat slower than those fed on ground grain, and requires more food to produce a pound of growth.

Ground bald barley made a better growth than the unground. To one who watched the experiment, the wonder is that the results are not still more in favor of the ground grain. Bald barley is smooth and very hard; harder than the hardest wheat. A large part of it when fed unground, passed through the alimentary canal whole and undigested. In the course of the day, these grains would be again and again eaten from the floor of the pen. It is possible that the same grain passed through a pig from three to five times. Each time some of the grains would be cracked and digested. The small difference in the results of the ground and unground, would seem to indicate that eventually most of the grain was digested, but the pigs certainly earned all they ate.

Ground vs. Whole Grain.

	Number of Tests.	Average Weight at Beginning of Tests.	Average Daily Gain.	Average Daily Feed.		Food per pound of Growth.	
				Grain lbs.	Skim-milk qts.	Grain lbs.	Skim-milk qts.
Whole Corn	6	63	0.44	1.9	1.0	6.7	1.2
Ground Corn	6	62	0.52	2.4	0.8	5.8	0.9
Whole Bald Barley	4	58	0.65	2.0	1.8	3.7	1.8
Ground Bald Barley	4	60	0.77	2.3	1.0	3.2	1.0
Whole Common Barley	3	43	0.44	1.9	0.7	5.2	0.9
Ground Common Barley	3	43	0.47	1.9	0.7	4.7	0.9

Average Results of Ground vs. Whole Grain.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
				Grain lbs.	Skimmilk qts.	Grain lbs.	Skimmilk qts.
Average Whole Grain alone	8	59	0.28	1.9		7.4	
Average Ground Grain alone	8	66	0.37	2.2		8.1	
Average Whole Grain and Skimmilk	5	54	0.87	2.0	3.1	2.3	3.4
Average Ground Grain and Skimmilk	5	57	0.74	2.4	2.2	2.6	2.4
Average Whole Grain	13	57	0.55	2.0	1.2	5.5	1.3
Average Ground Grain	13	57	0.59	2.3	0.9	4.8	0.9

The gain for grinding is largest in the case of bald barley, and least with common barley. The gains

amount to about one-half more in the case of bald barley, one-fifth more for corn, and about one-twelfth more for common barley. This means that two bushels of ground bald barley made as much gain in two weeks, as three bushels of whole bald barley did in three weeks. The grinding increased the rate of growth and decreased its cost.

There is no doubt but that the increased returns for grinding the bald barley more than paid the cost of grinding. It is equally certain that grinding the common barley did not pay for itself. In the case of the corn, circumstances would determine which was the more profitable. We bought this corn at fifty cents per hundred, with two cents per hundred added for grinding, the labor of hauling being the same in both cases. Then, if grinding added a fifth to its value, it would pay to have it ground. Had we raised this corn, it would have cost us five cents a hundred to get it ground, beside the labor of hauling from the farm to the mill and return. The addition of a fifth to its value, would not, under these conditions, pay for the labor and the expense.

Whole Corn versus Whole Bald Barley.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed		Food per pound of Growth	
				Grain lbs.	Skmi-milk qts.	Grain lbs.	Skim-milk qts.
Whole Corn	5	66	0.30	1.9	0.4	7.3]	0.7
Whole Bald Barley	5	72	0.40	1.9	0.4	5.2	0.5

The whole bald barley does better than the whole corn. Indeed, the whole corn did the poorest of any feed. The young pigs did not seem to be able to grind it easily, and as is well known, corn is largely lacking in the elements necessary to make bone and muscle. Bald barley is especially rich in both these ingredients.

Whole Corn versus Whole Common Barley.

	Number of Tests	Average Weight at Beginning of Test	Average Daily Gain.	Average Daily Feed.		Food per pound of Growth.	
				Grain lbs.	Skim-milk qts.	Grain lbs.	Skim-milk qts.
Whole Corn	5	68	0.36	2.0	0.6	7.6	0.7
Whole Common Barley	5	67	0.44	2.3	0.4	6.0	0.6

The whole common barley has given a quarter more growth per day than the whole corn and has produced this growth with a quarter less grain and a little less of the skimmilk. The differences in favor of the whole common barley are just about the same as those in favor of the whole bald barley.

Whole Corn versus Ground Corn and Ground Common Barley.

	No. of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed Grain lbs.	Food per lb. of Growth. Grain lbs.
Whole Corn	2	50	0.18	1.5	9.3
Common Barley	2	33	0.25	1.6	6.1

Since barley has given better results than corn, and ground grain than unground, it is natural to expect what these tests show, that ground corn and ground common barley have given considerably better returns in growth and the cost of that growth than the whole corn.

Ground Corn versus Ground Bald Barley.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
				Grain lbs.	Skimmilk qts.	Grain lbs.	Skimmilk qts.
Ground Corn	5	63	0.55	2.6	0.8	5.6	0.9
Ground Bald Barley	5	67	0.74	2.4	0.8	3.6	0.8

The results speak very highly in favor of the good qualities of ground bald barley as a food for young pigs. We paid fifty cents per hundred pounds for this grain, and, allowing twenty-five cents per hundred pounds for the skimmilk, makes a cost of 2.2 cents for the food used in producing a pound of growth. When it is remembered that this was in cold weather, with scant shelter, it will be seen how strong a testimonial this is in favor of bald barley.

Ground Corn versus Ground Common Barley.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
				Grain lbs.	Skimmilk qts.	Grain lbs.	Skimmilk qts.
Ground Corn	4	52	0.60	2.5	1.2	4.9	1.4
Ground Common Barley	4	47	0.70	2.4	1.1	4.3	1.1

In the tests the previous years of corn and ground barley, the results had been equivalent. These were tests with large and nearly grown pigs, the object being to fatten them. In the present tests with young pigs to produce growth, the barley shows its superiority to the corn. Both these results are in accordance with the chemical analysis of the grains already given. The two grains are closely alike in heat and fat-producing elements, while the common barley is better suited than corn to produce growth. It should be noted, however, that even here the results of the two grains are not greatly different.

Ground Corn versus Ground Corn and Ground Common Barley.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
				Grain lbs.	Skimmilk qts.	Grain lbs.	Skimmilk qts.
Ground Corn	3	44	0.69	2.1	1.7	3.7	1.8
Corn and Barley	3	53	0.94	2.3	1.3	3.5	1.5

The apparent results in favor of the mixed grain are due to the figures of only one of the three tests. The other two, give one slightly in favor of the corn, and the other slightly in favor of the mixture, the average being equivalent.

Whole Bald Barley versus Whole Common Barley.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
				Grain lbs.	Skimmilk qts.	Grain lbs.	Skimmilk qts.
Whole Bald Barley	5	82	0.41	2.2	------	5.5	------
Whole Common Barley	5	79	0.39	2.5	------	6.5	------

In spite of the hardness of the bald barley grains, the pigs received enough nourishment from them to produce as much growth as the common barley and from a fifth less grain.

Ground Bald Barley versus Ground Common Barley.

	Number of Tests.	Average Weight at Beginning of Test.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
				Grain lbs.	Skimmilk qts.	Grain lbs.	Skimmilk qts.
Ground Bald Barley	3	60	0.77	2.3	1.0	3.2	1.0
Ground Common Barley	3	50	0.68	2.7	0.8	5.0	0.6

This is the series of tests where both grains are at their best, and results confirm or are borne out by the chemical analyses, that bald barley is better adapted for producing growth than the common barley. Bald barley grew a pound of pork at a cost of 2.1 cents for the food eaten; while the common barley required 2.8 cents' worth of food.

Three more comparisons could be made between the mixture of ground corn and ground common barley, on the one side, and, on the other side, either ground bald barley or ground common barley, or the average of the results from ground corn and ground common barley fed separately.

Without going into the details of these comparisons, it may be said that the mixture of corn and barley has done better than ground common barley, and not so well as ground bald barley. Feeding corn and barley together has produced a quarter more growth on about a fifth less food than feeding the two grains separately.

FEEDING TESTS WITH STEERS.

During the winter of 1895–96 a test was made of feeding barley to steers, with and without beets, in comparison with corn and wheat. Some of the figures from this test have already been printed in Bulletin No. 34, of this Station. Only that part of the test will be mentioned here that refers to the feeding of barley.

There were four pens of steers. A weighed quantity of hay was given each day, and the amount left weighed. The column headed "hay" in the table means the amount actually eaten. All the barley fed was common barley, and all the grains were ground before feeding.

Record of Steer Feeding.

No. of Pen.	Hay.	Corn.	Wheat.	Barley.	Beets.	Gain in Weight per Head	Shrinkage in Shipping.
1	9,195	2,334		237	756	155	8
2	7,938	237	2,352		6,936	163	27
3	8,898			2,574		76	37
6	7,524		237	2,256	5,694	141	66

Corn versus Barley. A comparison of pens No. 1 and No. 3 is a test of corn and barley, each fed without beets. The two lots ate nearly the same amount of hay and much the same of grain. The extra grain eaten by pen No. 3 just about balances the extra hay and a few beets fed to pen No. 1. The amount of food eaten and the market value of that food are about equal. The growth is decidedly in favor of corn. Not only did the corn make a larger growth, amounting to 79 pounds per head, but this growth was so much firmer that it shrank less in shipment. The corn-fed steers weighed on the market 124 pounds more per head than the barley-fed. The barley-fed steers began to show soon after they were put on to the feed that they were not doing so well as those having corn. They ate their food up clean and with a fairly good appetite, but always looked worse than their neighbors on corn.

Wheat and Beets versus Barley and Beets. The amount of beets fed in each case is not so much different, when taken in connection with the difference of grain, but that the results may be considered as due to the difference in the feeding value of the wheat and the barley. The wheat and beets give considerable more growth than the barley and beets. Just as the steers fed on barley alone shrink more than those on corn alone, so those on barley and beets shrink more than those on wheat and beets. In both cases the barley does not seem to make so hard flesh and fat as the corn or wheat. Judged by the weights on the market, the wheat and beets have made almost double the gain in live weight of the barley and beets.

Barley versus Barley and Beets. The steers on barley alone had 450 pounds more of hay, and the others 1,646 pounds more of beets. To offset this thousand pounds of beets extra, the steers getting beets grew nearly twice as fast as those getting barley alone, gaining 141 pounds per head, while the barley-fed steers are gaining 76 pounds. The flesh made from beets is softer than that from grain. Those fed barley shrink 37 pounds in shipping; those having the beets in addition shrink 66 pounds. On the market the steers having barley and beets weighed 75 pounds each above their weight in December; while the steers eating barley alone had gained only 36 pounds. This extra growth upon the addition of the beets made a return of about three dollars per ton for the beets fed.

First Feeding Tests with Sheep.

Winter of 1895–'96.

The tests with lambs during the winter of 1895–'96 included barley, corn, wheat, beets, and a mixture of barley and corn. All the grains were fed ground. There were 220 lambs used in the experiments, divided into lots of about 35 head each.

There will be given here only those tests that relate more particularly to barley.

Feeding Record per Head--January 8 to April 13.

Pen.	Hay.	Barley.	Corn.	Wheat.	Beets.	Gain in Weight per Head.
1	300	86				27
2	294		86			28
3	321				375	22
4	227			77	218	26
5	181	32	56			26
6	191	32	56			26

The gain in weight of the pen eating barley is one pound less, and the hay eaten six pounds more than the pen eating corn. In other words, the barley and corn are

very nearly equal in feeding value, with the advantage slightly in favor of corn. All these grains were ground and the barley used was the common barley.

Barley gives about the same results as wheat and beets. If the extra shrinkage in shipping the sheep fed on beets could be taken into account, the results in favor of the barley would show more plainly.

Barley does much better than beets alone. If a comparison is made of beets alone, and wheat with beets, and then the results worked back to a comparison of wheat and barley, it gives almost exactly the same feeding value to each. Barley and corn fed separately have given a little better results than the two fed together. In the case of pens 5 and 6, barley was fed the first third, then barley and corn the second third of the time, ending with corn alone. The results were entirely unexpected. Theoretically this feed should give better results than either fed alone. Moreover, for the purpose of another experiment, pens 5 and 6 received a much better quality of hay than either pens 1 and 2. Nevertheless, the pens on the poor hay and the grain separately did better than on the good hay and the mixture of grain.

The difference in the results is so slight as to show a substantial agreement in the feeding values of the three grains, barley, corn, and wheat.

Second Feeding Test with Sheep.

Winter of 1896-'97.

The largest trials we have made with sheep were those of 1896–'97. There were 440 lambs used, divided into ten pens of about 45 head each.

All the pens received alfalfa hay. The other feeds used were as follows:—

Pen No. 1. Ground corn, beginning January 5, reaching one pound per day per head March 3, $1\frac{1}{4}$ pounds April 17, and changed on April 27 to $1\frac{1}{4}$ pounds whole corn.

Pen No. 2. Same, using ground bald barley until April 27, after that whole corn; but the quantity scarcely raised above a pound per head per day.

Pen No. 3. Same quantities and dates as pen No. 1, using whole bald barley, changing April 27 to whole corn.

Pen No. 4. Beginning January 5 on ground bald barley, changing February 16 to half ground bald barley and half ground corn, on March 30 to all ground corn, and on April 72 to whole corn. Quantities the same as in Pen No. 1.

Pen No. 5. From November 19 to March 14, 4 pounds per head per day of corn ensilage. Beginning March 6, ground corn added, reaching one pound per head per day March 16, raised to 1¼ pounds by April 15, and changed April 27 to 1¼ pounds whole corn.

Pen No. 6. Began November 19 with whole corn, two ounces per day per head; raised gradually reaching one pound on March 3, to 1¼ pounds April 17, and continued at this amount to May 17.

Pen No. 7. Same as pen No. 6, 'using ground corn and changing April 27 to whole corn.

Pen No. 8. Same as pen No. 6, using whole common barley, changing April 27 to whole corn.

Pen No. 9. Same as pen No. 6, using ground common barley, changing April 27 to whole corn.

Pen No. 10. Same as pen No. 6, using ground bald barley, but scarcely going above one pound per day per head, and changing April 27 to one pound whole corn.

The experiment progressed nicely until March 31, when the grain fed began to be raised above one pound per day per head. Pens Nos. 2 and 10, on ground barley, soon lost their appetite and got badly off-fed. Several lambs were taken sick and two died, apparently from indigestion. The grain fed was at once lowered, and, in the course of two weeks, their appetite returned; but they would never take more than the pound of grain per head per day. Pen No. 9, on ground common barley, got off-fed when the quantity was raised, but after a few days came back all right and took their 1¼ pounds to the end of the test. The lambs on whole bald barley, whole common barley, and both whole corn and ground corn, came up easily to the 1¼ pounds and continued this to the end of the test. The explanation of these results seems to be that the bald barley contains so large an amount of gluten that, when ground, it gathered into a sticky mass; but, when fed whole, much of the grain

passed the animal unbroken and undigested and what was cracked was so mixed with the hay as to make no trouble. About one pound per head per day seemed to be the limit of the digestive powers of these lambs on ground bald barley.

In the case of the ground common barley, analysis shows that it contained much less gluten than the bald barley, and in addition the hull would tend to keep the gluten grains from gathering into a mass.

On account of the changes in feed and the trouble with the bald barley, it seems best to divide the winter's test into four periods.

First Period. November 19 to January 5.

Pens 1 to 4 receive no grain.
Pens 5 to 10 receive a small amount of grain.

Second Period. January 5 to April 6.

All the pens receive grain up to one pound.

Third Period. April 6 to April 27.

Pens 2, 9, and 10 more or less off-fed.
Other pens raised to $1\frac{1}{4}$ pounds grain per day.

Fourth Period. April 27 to May 17.

All pens given whole corn.

The most reliable comparisons are those obtained from November 19 to April 6; but, in the case of the pens that had no trouble, the comparisons can be carried to April 27 or to May 17.

The amounts of feed eaten and the gains in live weight are given in the following tables. The results are all calculated to 40 sheep in each pen.

Feeding Records November 19, 1896, to May 17, 1897.

	Pen 1.			Pen 2.			Pen 3.		
	Hay.	Ground Corn.	Whole Corn.	Hay.	Ground Bald Barley.	Whole Corn.	Hay.	Whole Bald Barley.	Whole Corn.
Nov. 19—Jan. 5	4,730			4,889			4,930		
Jan. 5—Apr. 6	9,687	2,555		10,295	2,502		10,273	2,497	
Apr. 6—27	1,640	1,010		1,349	877		1,559	996	
Apr. 27—May 17	912		1,125	1,102		900	1,234		1,125
Total	16,969	3,565	1,125	17,635	3,379	900	17,996	3,493	1,125

	Pen 4.				Pen 5.				Pen 6.	
	Hay.	Ground Bald Barley.	Ground Corn.	Whole Corn.	Hay.	Ensilage.	Ground Corn.	Whole Corn.	Hay.	Whole Corn.
Nov. 19—Jan. 5	4,432				2,133	8,886			4,189	382
Jan. 5—Apr. 6	10,183	847	1,650		5,871	11,040	1,061		8,645	2,719
April 6—27	1,718		996		1,626		995		1,619	995
Apr. 27—May 17	1,119			1,125	1,390			1,125	1,117	1,124
Total	17,442	847	2,646	1,125	11,020	19,926	2,056	1,125	15,570	5,220

	Pen 7			Pen 8			Pen 9			Pen 10		
	Hay.	Ground Corn.	Whole Corn	Hay.	Whole Common Barley.	Whole Corn.	Hay.	Ground Common Barley.	Whole Corn.	Hay.	Ground Bald Barley.	Whole Corn.
Nov. 19—Jan. 5	4,032	370		4,180	367		4,815	370		4,032	357	
Jan 5—April 6	8,366	2,682		8,731	2,685		8,363	2,635		7,258	2,685	
April 6—27	1,580	996		1,911	996		1,273	917		1,472	825	
April 27—May 17	1,238		1,125	2,034		1,125	1,186		1,125	1,196		900
Total	15,216	4,048	1,125	16,856	4,048	1,125	15,637	3,922	1,125	13,958	3,867	900

Total Feed November 19, 1896, to May 17, 1897.

Pen.	Principal Grain Feed.	Hay.	Grain.	Ensilage.	Gain in Live Weight.
1	Ground Corn	16,969	4,690		38
2	Ground Bald Barley	18,183	4,279		33
3	Whole Bald Barley	17,996	4,618		38
4	Ground Corn and Barley	17,442	4,618		37
5	Ensilage and Ground Corn	8,946	3,181	19,926	40
6	Whole Corn	14,570	5,220		44
7	Ground Corn	15,216	5,176		42
8	Whole Common Barley	16,856	5,173		40
9	Ground Common Barley	15,637	5,047		38
10	Ground Bald Barley	13,958	4,767		38

Gains in Weight.

Pen.	Live Weight.				Gains in Live Weight.							
	Nov. 19.	Jan. 5.	Apr. 6.	May 17.	Nov. 19—Jan 5.	Jan. 5—Apr. 6.	April 6—27.	Apr. 27—M'y 17	Nov. 19—Apr. 6	Nov. 19—Apr. 27	Apr. 6—May 17	Nov. 19—May 17
1	53	59	79	91	6	20	8	4	26	34	12	38
2	52	57	81	85	5	24	—1	5	29	28	4	33
3	51	57	81	89	6	24	2	6	30	32	8	38
4	52	58	81	89	6	23	6	2	29	35	8	37
5	43	56	71	83	13	1[illegible]	9	3	28	37	12	40
6	43	55	79	87	12	24	4	4	36	40	8	44
7	42	51	74	84	9	23	7	3	32	39	10	42
8	44	52	75	84	8	23	6	3	31	37	9	40
9	44	52	73	82	8	21	5	4	29	34	9	38
10	43	52	74	81	9	22	2	5	31	33	7	38

Light versus Heavy Feeding of Grain.

Pens Nos. 1 to 4 were fed no grain during the first eight weeks of the winter, while pens Nos. 6 to 10 received no grain from the start. The amount of grain given was not large, only 9 pounds per lamb, but the growth made during these eight weeks shows the effect of even this small amount. Pens Nos. 1 to 4, average growing 6 pounds per head; while pens Nos. 6 to 10 grow 9 pounds each. Three pounds of growth as a result of nine pounds of grain is making mutton at a very cheap rate.

For the rest of the winter the grain feeding is not much different. Pens Nos. 1 to 4 receive 114 pounds of grain per head and pens Nos. 6 to 10 receive 116 pounds. Omitting pen No. 6 with a much greater gain, due to a different kind of feed, the two lots retain to the end this difference of three pounds' gain in live weight. In other words, feeding nine pounds of grain in November and December has given three pounds more of lamb to market in May. This represents a net profit of 15 cents per lamb, or nearly one-third of the profits of an ordinary winter's work.

Whole Grain versus Ground Grain.

Pens Nos. 7 and 9 received ground grain, while pens Nos. 6 and 8 received the same amount of the same kind of grain fed whole. From November 19 to April 6, while being fed these rations, pen No. 6 gains 4 pounds per head more than pen No. 7 and pen No. 8 gains 2 pounds more. For the whole season the average is 2 pounds per head in favor of the whole grain. Thus, the grinding of the grain was not only time and labor lost but was an actual detriment to the sheep.

What Grain is Best for Sheep.

In previous years when corn has been fed in comparison with wheat, the results have been the same. This year, in comparing corn with common barley and bald barley, the corn is far ahead. Whole corn fed to pen No. 6 makes 4 pounds more of growth than whole common barley with pen No. 8. Ground corn to pen No. 7 gives 4 pounds more weight than ground common barley to pen No. 9. Corn makes 4 pounds more of growth than common barley, whether weights are taken April 6 or May 17.

It may seem to some that this is attaching a great deal of importance to a small amount of growth; that only four pounds difference in a whole winter's feeding of 180 days, is scarcely enough to show much difference in the feeding value of the various grains used. It must be remembered, however, that these small differences in growth are what determine the profit or loss on the winter's work. Lambs are fed here on a rather narrow margin. If one could be sure of paying all expenses and netting 30 cents per lamb, above the market price of hay and grain fed, it would be considered worth trying, while 50 cents per head is counted as a good return. On this margin, the difference in the above results, between corn and common barley, represents half the net profits of the whole season.

The comparisons of bald barley with the other feeds are not so easy or satisfactory. Bald barley contains so large an amount of gluten that the lambs could not handle more than a pound per head per day. It is necessary to make all comparisons with this grain before April 6, as after that date the lambs were more or less off feed and did poorly.

From November 19 to April 6, pen No. 2, on bald barley, gains three pounds more than pen No. 1 on corn, and pen No. 10 on bald barley, gains one pound less than pen No. 7 on corn. The average results are, therefore, nearly even, with a slight advantage in favor of bald barley. It is well to notice here that, during this period, the larger and stronger lambs of pen No. 2 seemed better able to handle this rich bald barley than the smaller lambs of pen No. 10, gaining two pounds more on slightly less feed. The results indicate strongly the high feeding value of bald barley for lambs, but they just as strongly emphasize the great danger of overfeeding. It would be easy, from the figures already given, to construct a theory that the perfect feed would be bald barley at the beginning and corn at the end. But, unfortunately for the theory, this is just what was tried with pen No. 4. The results up to April 6 are satisfactory, but the lambs did not respond to heavy feeding afterwards as those did that had received nothing but corn.

It seems a fair conclusion from all the results that, while bald barley has as high a feeding value as corn, it is in no way superior to it. The comparison of bald barley and common barley is somewhat in favor of the bald barley. The whole bald barley did decidedly better than the ground bald barley, not because it really had any more feeding value, but because it could not gather into a sticky mass and clog digestion as did the ground grain. As a fact, a large amount of the bald barley fed whole passed through the lambs undigested, and still they did better on it than on the ground corn, or ground corn and ground bald barley.

SUMMARY.

Good crops of barley can be grown in Colorado if good land is used and attention given to proper irrigation.

Malting barley does well in Colorado, but most of the barley grown in the State is used for feeding purposes.

On the average, bald barleys have not yielded as many pounds of grain, i. e., as much animal food per acre as some of the common barleys.

California barley has given the best yields on the

College Farm, an average of over a ton of grain per acre.

Bald barley has proved the best to grow in the mountains for grain or hay.

Analysis of barley shows that both the common barley and the bald barley contain about the same amount of total animal food; that this amount is closely equivalent to the food material in wheat or corn, and more than in either bran or oats.

Barley contains about the same elements to produce growth of bones and muscles in young animals as wheat, and more than in corn.

Bald barley contains more bone and muscle producing food than common barley.

For the production of fat in fully grown animals, analysis shows bald barley, common barley, wheat and corn to be practically equivalent.

Barley has been tested at the College Farm as feed for pigs, steers, and sheep.

Ground common barley and whole corn, fed in moderate weather to pigs of a hundred pounds or more in weight, have produced the same amount of growth.

Fed to Young Growing Pigs in Winter in Open Pens:

1. Ground bald barley has done one-half better than whole bald barley.

2. Ground corn has done one-fifth better than whole corn.

3. Ground common barley has done one-twelfth better than whole common barley.

4. Whole bald barley gave better results than whole corn as did also whole common barley.

5. Ground bald barley made the most rapid growth of any of the feeds used and produced this growth on the least food. One pound of growth was made with 3.6 pounds of grain and 0.8 quarts of skimmilk at a cost of 2.2 cents for the food.

6. Ground corn required one-half more food than ground bald barley to make a pound of growth.

7. Ground corn and ground common barley had about the same feeding value, with the slight difference in favor of barley.

8. Ground common barley required one-third more food for each pound of growth than ground bald barley.

9. Ground common barley and ground corn fed together have produced better results than the same grains fed separately.

In the Feeding Tests With Steers

1. Ground corn made considerably more growth than ground common barley. This growth was also much firmer and shrank less in shipping. The difference between the two amounted to the entire profits of the feeding.

2. Ground wheat and beets surpassed ground barley and beets in about the same proportion that the corn excelled the barley.

3. Beets added to a ration of barley produced more growth, but only enough to return three dollars per ton for the beets fed.

In the Feeding Tests With Lambs, 1895-6.

1. Ground common barley and ground corn have given nearly equal results, with the slight advantage in favor of corn.

2. The results of ground wheat and ground common barley have been almost identical.

3. Barley and corn fed separately gave a little better results than the two fed together.

In the Feeding Tests With Lambs, 1896-7.

1. Giving grain from the start produced more and cheaper growth, than feeding six weeks on hay alone before giving grain.

2. Whole grain yielded more rapid and cheaper growth than ground grain.

3. Corn, whether ground or whole, gives more growth than common barley, the difference in favor of corn being greater than it was the year before.

4. Bald barley made slightly more growth than corn when given in moderate feeds; but when the amount was raised above a pound per day per head, the lambs were unable to digest it and went off feed.

5. Corn and bald barley mixed give no better results than corn alone.